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TECHNICAL REPORT
NATICK/TR-79/038

INVESTIGATION AND ASSESSMENT OF HARDWARE FOR GUIDANCE OF GLIDING AIRDROP SYSTEMS

by

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Contract Number: DAAK60-78-C-0021

FEBRUARY 1979

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UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Aero-Mechanical Engineering Laboratory

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NATICK TR 79/038	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): INVESTIGATION AND ASSESSMENT OF HARDWARE FOR GUIDANCE OF GLIDING AIRDROP SYSTEMS	5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT, 9 Jan 1978 – 31 Dec 1978
	6. PERFORMING ORG. REPORT NUMBER: FWD79-2066
7. AUTHOR(s): Joseph R. Hennel, Lynn A. Gerig, Hugh R. Reeder, Jimmie R. Schiele	8. CONTRACT OR GRANT NUMBER(s): DAAK60-78-C-0071
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Magnavox Government and Industrial Electronics Co. 1313 Production Road Fort Wayne, Indiana 46808	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62210A 1L162210D283 AA D&D BG
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of the Army U.S. Army Natick Research and Development Command Kansas Street; Natick, Massachusetts	12. REPORT DATE: 28 February 1979
	13. NUMBER OF PAGES: 295
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 285	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Airdrop	Anemometer	Battery	Cone-of-Silence
Airspeed Indicator	Data Processing	Guided Flight	Servo System
Altimeter	DME	Sensors	Gliding Canopy
Antenna	Homing	Signal Generation	
ADF	DF Antenna	Inertial Heading	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Assessments were made of hardware and guidance techniques for Gliding Airdrop System employing partial and full-state guidance schemes. From the available candidate guidance schemes, the Army selected the following ones for further study to prepare system specifications and preliminary cost estimates: Minimum Cost Radial Homing, Radial Homing with Ennance Manual Control, Cone-of-Silence Homing, and Full-State Guidance. Airdrop systems with payload capacities of 227 KG, 909 KG, and 6800 KG are addressed.

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Summary

The object of Phase I of this program was to provide preliminary screening of hardware and guidance techniques to assist in selection by the Government of several airdrop systems for further definition during Phase II.

Specific hardware considered included those sensors that provide the input parameters necessary for the candidate guidance techniques, and the data processor needed to process the input parameter data and to produce the command signal to the steering actuator.

Numerous manufacturers of potentially useful hardware were contacted and the equipment specifications that they submitted were analyzed to assess their feasibility in various guidance schemes, before being stored for use in generating system specifications during Phase II.

The feasibility of those guidance schemes listed in the solicitation were evaluated and their potential assessed. Those schemes deemed to warrant further effort during Phase II were identified.

From the recommended guidance schemes presented in the Phase I report, the Army selected Minimum Cost Radial Homing, Radial Homing with Enhanced Manual Control, Cone-of-Silence Homing, and Full State Guidance CHMS schemes for further study. These studies produced a proposed hardware design and a cost estimate for each.

This program was aided by the technical guidance provided via discussions and memoranda from the COR Thomas Goodrick.

This report covers Phase I briefly and Phase II in detail.

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1.0 INTRODUCTION

A number of candidate hardware items for airdrop systems were considered during Phase I of this program. Components suitable for the functions to be performed required identification and confirmation of their availability prior to generating system descriptions during Phase II. In addition to the hardware screening actions during Phase I, potentially useful guidance schemes also required evaluation.

1.1 Phase I

1.1.1 Hardware Assessment

During Phase I, efforts were concentrated on screening potential hardware vendors and securing technical specifications of their products for evaluation. Vendors were selected on the basis of familiarity with their products from previous uses, or by consulting listings under appropriate categories in product directories. Vendors contracted were either designers or manufacturers of products in the following areas:

- Aircraft Control
- Accelerometers
- Batteries
- Beacons
- Antennas
- Airspeed Indicators
- Altimeters (Barometric and Radar)
- Direction Finders and Homing Equipment
- Distance Measuring Equipment (DME)
- Gyroscopes
- Geophysical Instruments
- Hobby Type R/C Equipment
- LASER Telemetry and Ranging
- Microprocessors
- RADAR
- Radiolocation and Navigation

- Radio Receivers, Transmitters and Transceivers
- Synchros and Servos
- TACAN
- Telemetry
- Television
- Transducers

Approximately 400 vendors were initially contacted, and after screening for applicability to airdrop systems, data sheets and catalogs from about 125 vendors are retained in the project file.

It has proven surprisingly difficult to locate actual "off-the-shelf" hardware items. In many cases, a prototype has been built, the ability to meet the specifications confirmed, and specifications and data sheets prepared by the vendor. However, the item has not been produced in quantity, and for some items, production will not occur until a relatively large order for it is placed. Consequently, some vendors' assurances that an item is "off-the-shelf" may carry some reservations.

The vendor catalog and data sheet file is too voluminous for attachment as a part of this report. Represetative data sheets were provided as an appendix to the Phase I interim report and those of major components are included as an appendix to this report.

As was anticipated, the maximum difficulty was experienced in locating suitable instrumentation for measuring range and inertial heading. Precision DME's were found that exceeded the range accuracy requirements, but these devices are expensive. Surprisingly, the instrument judged most suitable for measuring inertial heading is a magnetic flux-gate transducer. Its usefulness is predicated largely on the gentle turns required during guidance, and the small roll angles that are required reduce the tilt error of this type sensor to an acceptably low value. A second choice of heading instrumentation is a directional gyro that is uncaged after air deployment during a short period of homing that establishes a reference heading.

For all other sensors, instruments were readily available that met all requirements. No off-the-shelf receivers or transmitters were evaluated that were capable of fully meeting the system requirements without some modification.

LASERs were not seriously considered as candidates, despite their excellent range accuracy and low detectability, largely because of the difficult initial acquisition problems that result from their extremely narrow beamwidth.

On-board television had not been considered a useful sensor during Phase I studies. However, discussion with the sponsor showed that it could be very useful, particularly if the airdrop system were to be manually guided from the drop aircraft. Consequently, it was included in the evaluation conducted during the Phase II effort.

1.1.2 Guidance Scheme Assessment

During the Phase I program, numerous candidate guidance schemes were considered. All of those listed in the RFP were found to be feasible. The conclusion was reached that if the most demanding scheme, CHMS, could be implemented, all of the other listed schemes were also feasible. It was also concluded that Direct Homing had little to offer, and that Radial Homing was a very viable contender. Conical homing showed considerable promise as a moderately complex guidance scheme, although it requires more sensors and computational capability than other partial-state techniques. A novel technique was identified that provides the controllable cone-of-silence required for Cone-of-Silence Homing. This same technique can provide measurement of the depression angle from the airborne unit to the target transmitter. This depression angle measuring technique can also be used in a Conical Homing guidance scheme in which the airdrop unit is steered to maintain constant the depression angle. This is a simplification of the Conical Homing Scheme described in the Phase I report of this contract.

1.2 Phase II

1.2.1 System Definition

After review of the Phase I report, the following guidance schemes were selected by the Army for further study.

a. Minimum cost radial homing
b. Radial homing with enhanced manual control
c. Cone-of-silence homing
d. Full-state guidance

The Phase II study effort produced a system specification for each of the above guidance schemes. In addition to identifying the components comprising each system, an estimate of the cost of producing the system in small and large quantities was also determined. Hardware selection was based upon the following criteria:

a. Ready availability
b. Acceptable systematic and random error characteristics
c. Compatibility with other components
d. Interface circuitry requirements
e. Cost

In the remaining paragraphs of this section, each of the selected guidance schemes is briefly described. Each is addressed in greater detail in Section 2.

1.2.1.1 Minimum Cost Radial Homing. - During radial homing the heading of the airborne unit is continuously directed toward the target transmitter (the homing deviation angle is maintained equal to zero). This simple technique is the only one that has been extensively used in the automatic homing aerial delivery systems that have been fielded to date. Its primary advantages are simplicity, minimum cost, and good performance in relatively low velocity winds.

To implement this technique requires only an RF transmitter located at the desired impact point, a DF system and a steering mechanism aboard the airborne package. A relatively broad cardioidal-shaped receiving antenna pattern is alternately lobed at 100 Hz, typically, to the left and to the right of the antenna boresight which is aligned with the heading vector of the guidance package. The received signal amplitudes are compared, and from this information the relative bearing to the transmitter is determined. An error signal is then generated that causes the steering system to alter the heading of the airborne subsystem by manipulating the proper control line to reduce the relative bearing to the transmitter to zero.

The process by which the heading error signal is generated is shown more clearly in figure 1. In this figure, β represents the relative bearing from the guidance antenna boresight to the target transmitter. This angle is also defined as the Homing Deviation Angle. The error signal, E_M, is the difference in amplitude of the received signal as the antenna is lobed to the left and to the right, and is equal to $E_L - E_R$. The method by which the cardioidal antenna pattern is generated is addressed in subsection 2.5.1.1.5.

Also required, but not a part of the homing function is a manual override capability that allows commanded left and right turns and straight flight for at least one airborne unit at a time within limited range of the landing area.

1.2.1.2 Radial Homing with Enhanced Manual Control. - This sytem uses the same radial homing components as above. However, the manual control capability is enhanced to permit:

a. Glide Ratio Control

b. Control of multiple units simultaneously airborne, with the option of providing data feedback such as heading, altitude, and airspeed. The use of video control may be considered.

1.2.1.3 Cone-of-Silence Homing. - This system incorporates radial homing with a well defined, controllable cone-of-silence generated by the placement of the sense antenna on the airborne unit. The data may be

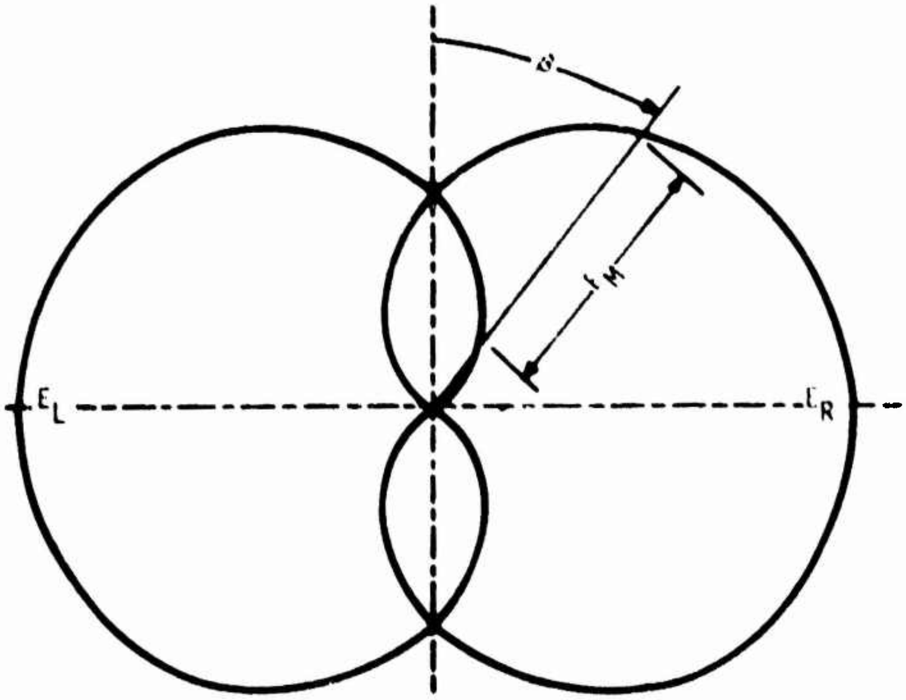

Figure 1. Heading Error Signal Generation

processed on board by a microprocessor to enhance the landing accuracy. A manual override capability is also provided.

1.2.1.4 Full-State Guidance. - This system incorporates some means for measuring each property required for specifying the full state of its position vector. The measurements are processed by a computer at some point in the system capable of filtering errors and implementing a previously identified guidance scheme such as CHM5*. Some form of manual override capability is also provided.

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* T. Goodrick, A. Pearson, and A. Murphy, Jr., "Analysis of Various Automatic Homing Techniques for Gliding Airdrop Systems with Comparative Performance in Adverse Winds," AIAA Paper No. 73-462, AIAA 4th Aerodynamic Deceleration Systems Conference, 1973.

2.0 GUIDANCE SYSTEMS

In this section an RF link analysis is presented to establish the receiver sensitivities and transmitter powers needed for each of the guidance systems. Each of the guidance schemes selected for further study is also addressed in detail. Finally, specific components and estimates of the system's cost is presented.

2.1 General

All of the systems will utilize essentially the same components for homing, and in the CHM5, a similar homing system will be used to measure the Homing deviation angle. Also, in all schemes, essentially the same manual override circuits are used. Normally, good performance can be obtained in homing and manual guidance with a minimum S+N/N of 10 dB. The link RF parameters will be developed based upon this assumption.

2.1.1 RF Signal Propagation Characteristics

The typical no wind glide angle of the airdrop system is 18.4 degrees, corresponding to an L/D of 3. An analysis was made of the minimum elevation angle that was necessary to provide free-space path losses for three terrain types at operating frequencies between 6 and 400 MHz. There were slight changes in minimum angle with frequency, but the major determinant was the type of terrain. For poor earth, the minimum elevation angle was found to be 11.8 degrees, for good earth 5.2, for sea water 2.7 degrees. Consequently, under all anticipated flight conditions, when the airdrop package is able to achieve the target, its elevation angle will be sufficient to insure that free space path loss calculations are valid

Further calculations were made to determine the path loss between isotropic antennas at the frequencies most likely to be of interest, and at the maximum range at which deployment is to occur. Frequencies between 3 and 400 MHz were considered, and the maximum range assumed considered a 6000 m drop altitude and a horizontal range of 14.24 km. The elevation angle to this release point is 23 degrees. The standard path loss equation [Equation (1)] was used for these calculations:

$$\text{Path Loss} = L_p = 32 + 20 \log F + 20 \log D \qquad (1)$$

where: L_p = Path loss between isotropic antennas in dB

F = Frequency in MHz

D = Slant range in kilometers

At 3 MHz the computed path loss is 65 dB, and at 400 MHz it is 107 dB. For subsequent link calculations, the 400 MHz value is used. Use of a lower frequency increases the safety factor of the link design.

2.1.2 Antenna Gain

The cardioidal antenna patterns are generated by a pair of spaced, phased monopoles mounted to the airdrop package, or by the in-phase summation of the outputs of a sense and a locp antenna. Table 1 was prepared from measured data (see Appendix A) to show the gain at antenna boresight and in the pattern minimum as a function of the depression angle.

Table 1. ADR-500/U Array Pattern Analysis

Depression angle degrees	Antenna gain at boresight dBi	Antenna gain in pattern null dBi
0	3	-2
20	1	-8.4
45	1	-18.5
60	-3	-16
75	-7.5	-19.5
Assumed maximum gain of array: 5 dBi		

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The ground station antenna is assumed to be a dipole exhibit - an elevation pattern that varies as the cosine of the elevation angle. The sum of the transmitting and receiving antenna gain in the pattern null for elevation angles to 75 degrees is shown in table 2. Also included in table 2 is the relative separation between an airdrop unit and a ground transmitter radiating a constant power that provides a constant input power level at the input to the receiver at all elevation angles.

2.1.3 Minimum Transmitter RF Power Requirements

The glide ratio of the airdrop system assures that the elevation angle to the airborne package will usually exceed 20 degrees. Using the path loss value computed from Equation (1), the system antenna gain at 20 degrees elevation angle from table 2, and a typical receiver sensitivity of -100 dBm for 10 dB S+S/N, the minimum transmitter power required to provide satisfactory performance in the antenna pattern null can be determined from Equation (2).

Table 2. Ground Station and System Antenna Gains, and Relative Range for Constant Receiver Power

Elevation angle degrees	Antenna gain dBi	Sum of transmit and receiver antenna gain in pattern null dBi	Relative range for constant received power
0	2	0	-
20	1.45	-7	1.0
45	1.0	-17.5	0.298
60	-4.0	-20	0.224
75	-9.7	-26.2	0.11

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$$P_T = L_P - G_A + S \qquad (2)$$

where: P_T = minimum transmitter power (dBm)

L_P = Path loss at maximum slant range (dB) = 108

G_A = System antenna gain at 20 degree elevation angle (dB) = -7

S = Receiver input power to provide 10 dB S+N/N (dBm) = -100

Solving Equation (2) using the above parameters:

$$P_T = 108 - (-7) - 100 = 15 \text{ dBm}$$

This corresponds to a power level of 25.1 mW.

The preceding RF Link Analysis is valid for all homing schemes except cone-of-silence homing which requires a different type of airborne antenna system. In this scheme, the airborne antenna system consists of a loop and a sense antenna summed in phase to produce a cardioidal antenna pattern. Although the directivity of a pattern generated by this technique is identical to that generated by phased linear radiators, its effective height and efficiency are poorer. Thus, since the power gain of an antenna is the product of its directivity and its efficiency, the antenna gain of the loop-sense type is less. To compensate for the lower gain of the DF antenna, a higher RF power must be transmitted.

For approximate sizing, a single turn loop with an area of $0.001\lambda^2$ was assumed. The power delivered to a matched load is given by Equation (3).

$$P_L = \frac{(E\, h_e\, Q_L)^2}{2R_L} \tag{3}$$

where: P_L = Power delivered to load (watts)

E = Field intensity (volts/meter)

h_e = Effective height of antenna (meters) = $2\pi A/\lambda$ = $2\pi x 10^{-3}$ m

Q_L = Loaded Q of tuned loop = 50

R_L = Load resistance (ohms) = 50

Solving equation (3) for the field intensity required to deliver -100 dBm to a 50 ohm load showed that a field intensity of 10.0 uV/m is needed.

This field intensity must be provided at the drop point which may be located up to 14.25 km from the beacon. Since the field intensity varies directly with distance from the transmitter, the field intensity at 1 km from the transmitter must be 14.25 times as great, or 142.5 uV/m.

A grounded one-quarter wavelength antenna provides a field intensity of 299 uV/m per kilowatt of radiated power at a distance of 1 km. The radiated power required to produce 142.5 uV/m at 1 km can be computed from Equation (4):

$$P_T = 1000\ (E_2/299)^2 \tag{4}$$

where: P_T = Radiated Power (watts)

E_2 = Desired unattenuated field (mV/m) at 1 km

Solving Equation (4) using a value of E_2 = 0.1425 mV/m establishes that the minimum radiated power level must be 2.29×10^{-4} watts.

Measurements made by Magnavox with similar antennas operating in the MF (1750 kHz) band showed that antenna efficiencies of 0.4 percent for a 14-foot center-loaded antenna, and 1.5 percent for a 35-foot top-loaded antenna, were typical. The input power required to produce 142.5 µV/m at 1 km was determined to be 5.7×10^{-2} watts for the 14-foot antenna and 1.52×10^{-2} watts for the 35-foot antenna. These power levels are not significantly different from those required at UHF. However, because atmospheric noise is considerably higher, particularly at night when long range, low-loss ionospheric propagation paths exist, a larger safety factor is suggested for an MF system relative to that required by a UHF system, to insure that the desired signal exceeds the undesired interfering noise level.

2.2 Basic Radial Homing Guidance System

2.2.1 General

In its most basic form, the radial homing guidance system contains a directional antenna, a receiver and a steering mechanism which maintains the airborne unit on a homing heading toward an RF source on the ground until ground contact occurs. This type of cargo delivery system can be made available with the following options:

a. Basic radial homer

b. Radial homer with manual steering

c. Radial homer with manual steering and step input pitch control

d. Radial homer with manual steering and proportional pitch control

A block diagram of the basic radial homing canopy guidance system is shown in figure 2. The blocks shown in this diagram are essential to all radial homing systems. Options to the systems are exercised by adding additional blocks to this basic radial homer

2.2.2 Airborne Sybsystem

2.2.2.1 Directional Antennas. - Tradeoffs to obtain a low cost directional antenna for this application generally lead the designer toward the UHF frequency band because of package dimensions versus RF wavelength requirements. Other factors considered require that the externally mounted antennas on the guidance package be retractable, so that they do not interfere when the canopy, guidance package, and cargo are combined into a droppable package. This requires that some means of antenna stowage and automatic antenna erection be included in the guidance package so that the antanna may be deployed after the cargo is released from the aircraft. In addition, the antenna must be capable of surviving the effects of guidance package tumbling during ground impact.

An antenna which meets the preceding requirements at minimum cost is a simple flexible-spring steel blade antenna manufactured by Magnavox. A typical antenna of this type is shown on Magnavox drawing 955953 in Appendix E. These monopole antennae have adequate flexibility to be manually bent to lie against the surface of the guidance package when rigged to the canopy and cargo. The spring steel material allows the antenna to erect after package deployment when the canopy and cargo separate.

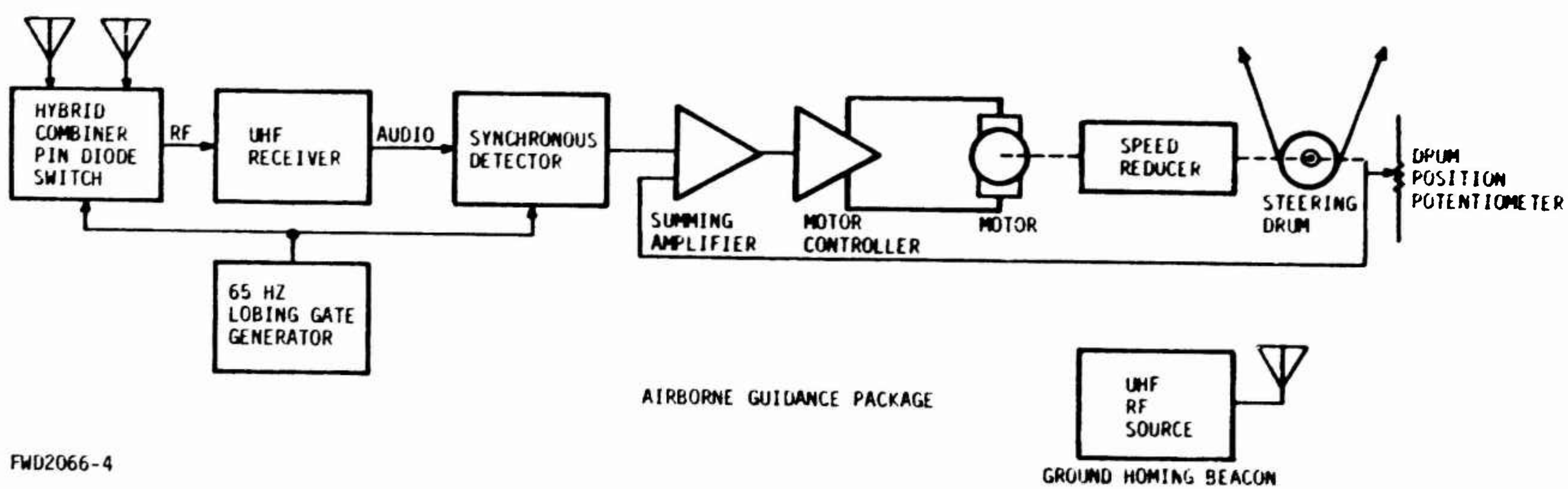

Figure 2. Basic Radial Homing Canopy Guidance System

When ground impact occurs, the flexibility of these antennas allows them to survive the random flexing which will occur. If antenna breakage does occur, replacement costs and effort are minimal. This type of antenna has successfully been used previously by Magnavox on other radial homing guidance packages.

To meet the directional requirements, two of these antenna are spaced at approximately 1/4 wavelength to produce the cardioid antenna patterns shown in figure 3. These antennas are normally mounted on the bottom of the guidance package which provides the required ground plane. When the RF output of the two antennas is properly phased and combined, the resulting cardioid pattern maximum can be alternately lobed left and right to provide the directional sense required of a homing antenna.

The cost of a monopole antenna of this type is approximately $10/pair. Due to the low cost of this antenna, and its other merits, no other antenna was considered for the basic radial homing system.

2.2.2.2 Antenna Pattern Lobing Switch. - To provide the required antenna lobing, Magnavox has available a 90° hybrid/steering diode printed circuit card assembly which is normally a component used in the Magnavox Model 717-CA VHF Homing Adapter. A description of the Model 717-CA Homing Adapter and its theory of operation has been included in Appendix C.

The required printed circuit card assembly, Magnavox Part No. 917563-801, is available at an approximate cost of $142.

The major contributor to the cost of this assembly is the 90° hybrid signal combiner. If quantity requirements justified the engineering costs, a less expensive 90° hybrid could be developed using either coaxial or strip line techniques provided the entire UHF band need not be covered.

2.2.2.3 UHF Receiver. - The UHF Receiver selected for this application is a fixed frequency receiver which is used as subassembly of the ARC-164 UHF communications transceiver. The receiver is normally used as the Guard frequency receiver and is fixed tuned to 243.00 MHz by means of a crystal controlled local ascillator. Tuning to other fixed frequencies is easily accomplished by replacing the crystal normally used with one processed to produce the desired frequency. Other modifications to the receiver printed circuit card assembly are required, but these primarily consist of deleting components not required for this application.

Performance specifications for this receiver are as follows:

Sensitivity:	2.8 μV for 10 dB $\frac{S+N}{N}$
Audio Output	2.4 V P-P/600Ω
AGC (Referenced to 1 MV)	
Input 4 μV	Δe_o -5 dB
Input 500,000 μV	Δe_o +1.8 dB

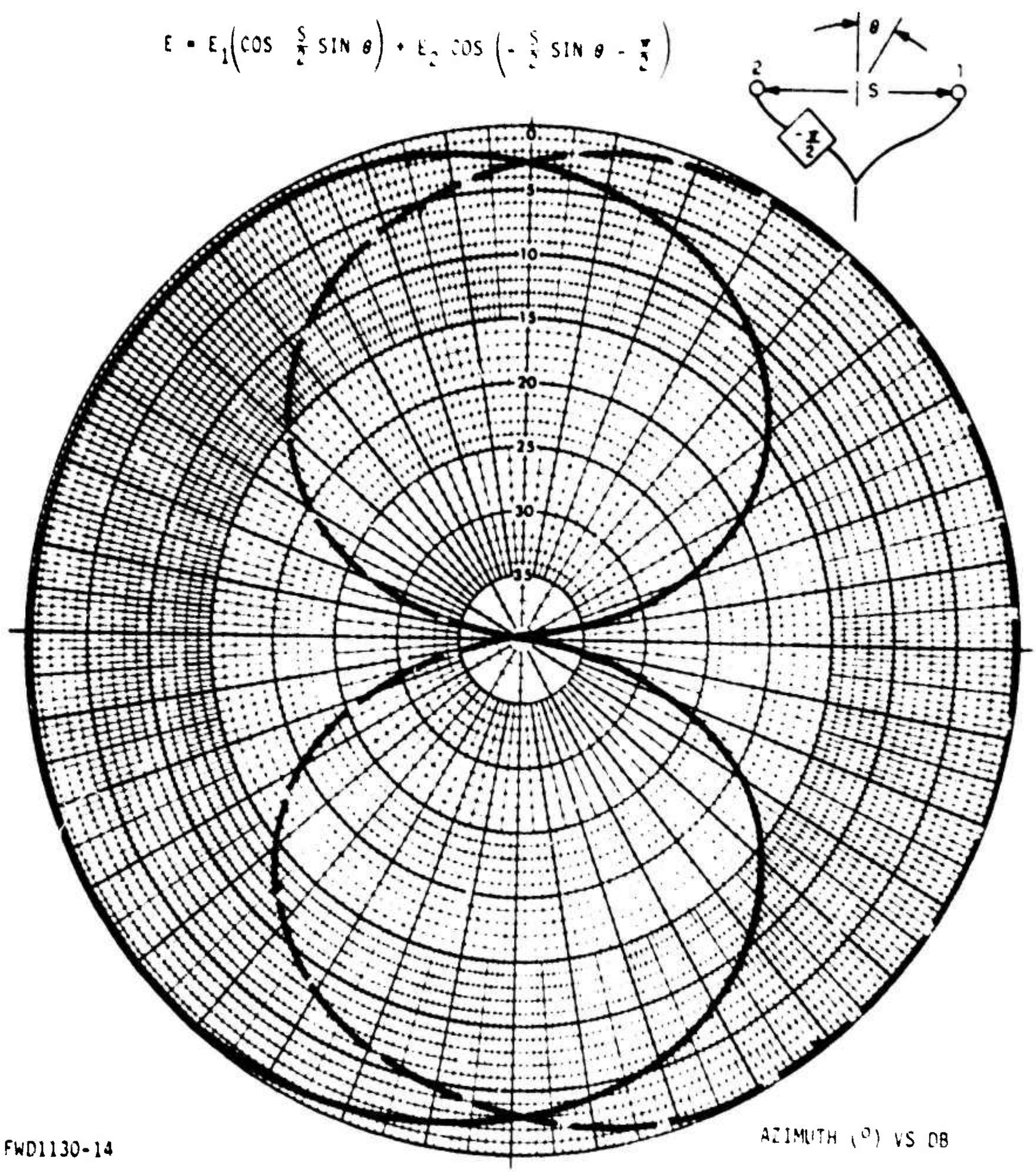

Figure 3. Switched Cardioid Polar Plot

Distortion (50% Modulation)	
1 kHz	7.2%
100 Hz	7.8%
Audio Response (1 kHz Ref)	
100 Hz	0 dB
9 Hz	-3 dB
5100 Hz	-3 dB
IF Bandwidth	
6 dB	±35 kHz
60 dB	±70 kHz
Input VSWR	<1.1:1
Image Rejection	-58 dB
Power Requirements	+12 Vdc (9 Vdc min)
Current Drain	47 ma @ 12 Vdc
Dimensions	5" x 4.75" x 0.625"
Weight	10 oz.

This receiver is available from Magnavox at an approximate cost of $178 each.

Due to the cost, availability and desirable form factor, no other receiver was considered for this radial homing application.

2.2.2.4 Synchronous Detector. - When considering the components shown in figure 3, the interface between the receiver audio output and the steering servo summing input will be unique and different depending upon the presence or absence of manual control options. This section of the basic block diagram normally cannot be fulfilled by means of an "off the shelf" component unless the customer desires the same options produced for a previous customer.

For the basic radial homing guidance system, this section contains very little circuitry. The purpose of the synchronous detector is to provide the steering error signal to the steering servo. In its minimum cost configuration, this requirement may be met by circuitry shown in figure 4.

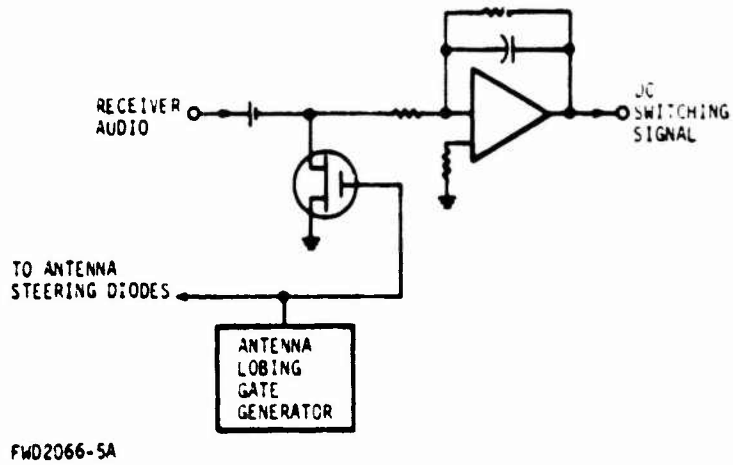

Figure 4. Minimum Cost Synchronous Detector

The above circuitry will provide a DC output the amplitude of which is proportional to the amplitude of the 100 Hz signal at the output of the receiver. The polarity of its output will depend upon the phase of the 100 Hz modulation relative to the phase of the antenna lobing signal. Since the required circuitry is minimal, it would normally be combined on the same printed card assembly used by the Antenna Lobing Gate generator.

This concept has been successfully used previously by Magnavox in its manned parachute homing system, the Halo Homer.

The circuit card assembly required to perform both the synchronous detector and the antenna lobing gate generator would cost approximately $50 plus engineering costs required to produce the printed circuit card.

2.2.2.5 Steering Servo. - The steering servo required for the basic minimum cost radial homer consists of an error summing amplifier, a motor controller, the drive motor, a reducing gearbox, the steering drum, and a position feedback potentiometer.

As shown in the block diagram of figure 3, the summing amplifier accepts the steering error signal from the synchronous detector and compares it with the position analog provided by the drum position potentiometer. If a difference is present, the summing amplifier provides an error signal which causes the motor controller to drive the motor which, in turn, re-positions the steering drum and its followup potentiometer until its output is equal to the synchronous detector output.

For the purpose of this report, servo system components for canopies with three different load capacities, 500 pound, 2000 pound, and 15,000 pound will be selected.

The design goals for performance parameters of the control actuators will be as follows:

Capacity (pounds)	500	2000	15,000
Maximum Deflection (inches)	24	48	79
Maximum Rate (inches per second)	6	12	20
Control Force (pounds)	25	150	750

2.2.2.5.1 Position Feedback Element. - Inherent in any position servo is a position feedback element which provides present position information to the servo summing amplifier. Numerous position indicators, many of them rather sophisticated digital encoders, are available. However, since the servo required for radial homing has very modest accuracy requirements and since a linear potentiometer is compatible with the synchronous detector DC input to the summing amplifier, the linear potentiometer was the only position feedback element considered for this application.

The required potentiometer need not be a precision type. Most general purpose good quality wirewound or film potentiometers will have adequate linearity, resolution, and temperature characteristics. Many general purpose multiturn potentiometers are available as catalog items at prices between $10 and $15. None were singled out as being best for this application.

When minimum cost is the goal, it is essential that the method of mechanically coupling the position feedback device to the steering drum be considered carefully. Coupling with gears is to be avoided from both a cost and performance standpoint. The most cost effective method is simple direct coupling of the potentiometer shaft to the steering drum shaft. Since the steering drum is a multiturn device and since standard multiturn potentiometers are limited to a maximum of 10 turns, direct coupling requires that a ±5 turn limitation be placed upon the steering drum. Fortunately, this constraint is compatible with the motor/gearhead/drum parameters when each is selected for optimum performance.

2.2.2.5.2 Steering Line Actuator Considerations. - One of the rules established initially was that the steering turn rates required to correct for canopy heading errors were to be proportional to the amplitude of the homing deviation angle. Since the relationship between steering line displacement and canopy turn rate is reasonably linear, the simplest actuator which provides the required proportional turn rates would be a drum winch that reels in the steering line a distance which is directly proportional to the homing deviation angle error. A brief period of time was spent considering other schemes of steering line deflection, but none were found which could compete with the winch drum for simplicity and minimum cost.

With the drum configuration firmly established, the optimum drum size was considered. The maximum drum size was obviously constrained by the size of the external package which made the largest practical size

less than 12 inches in diameter. The largest possible drum has the advantage of reducing the number of turns the drum must store when the turn rate of the canopy is maximum. This reduces the width of the drum and the possibility of drum diameter buildup as line overlap occurs. An undesirable characteristic of a large drum is that the torque applied to the output shaft of the drum drive gear box increases as the drum diameter increases, and can approach impractical amplitudes. A large drum also requires a large gear reduction between the motor and the drum which can reduce efficiency, and force the use of more expensive multistage helical gear or spur gear speed reducers.

A small drum eliminates the high output torque and high gear ratio requirements of the large drum but has the disadvantage of requiring a multilayer buildup of the incoming steering line. This can result in a variable drum diameter as the line builds up and, subsequently, variable gear ratios and variable line rates. Also the small drum will add to line wear as taut line is forced to slide over taut line already stored on the drum.

The optimum drum diameter and width was initially established at the diameter required to store 2 to 4 turns of incoming line. This will allow single layer stowage of a completely retracted line on a reasonably narrow drum. (Subsequent calculations indicated this drum diameter to be compatible with available motors and reduction gears, also.)

The actual width of the steering drum will depend upon the diameter of the steering line and whether the guidance package uses a single servo steering system or a two servo steering system. A single shaft/two drum steering system must pay out line off one drum while the other drum is taking in line, hence each drum must be wide enough to store twice the required length of line. A two servo steering system is not required to store this extra line.

Preliminary Drum diameter selections for the various size canopies were initially and somewhat arbitrarily established as follows:

a. 15,000 pound canopy (two meter pull, 4 turns) - 6.26 inches

b. 2,000 pound canopy (1.2 meters pull, 4 turns) - 3.76 inches

c. 500 pound canopy (24 inches pull, 2 turns) - 3.82 inches

The preceding drum diameters require the following drum shaft torques:

a. 15,000 pound canopy (750 pound pull) - 2,347 pound inches

b. 2,000 pound canopy (150 pound pull) - 282 pound inches

c. 500 pound canopy (25 pound pull) - 47.8 pound inches

2.2.2.5.3 Servo Component Selection

2.2.2.5.3.1 General. - The components which make up the drum drive servo are as follows:

a. Servo motor
b. Reduction gear
c. Motor electronic drive
d. Battery power pack
e. Steering drum
f. Followup potentiometer.

Except for the preliminary estimates of drum diameters, none of these components can be selected upon individual merits but must be selected for characteristics which are mutually compatible and fit the requirements of the overall servo. In developing the characteristics of the overall servo, the following requirements were established:

a. Accuracy. - The accuracy requirements for the servo are very modest. An overall position accuracy of ±5% will be adequate for successful radial homing. This eliminates the need to use components providing high accuracy if premium components result in higher cost.

b. Power. - The use of battery power is inherent in the guidance system requirement. All components in the servo system must be selected for compatibility with battery (DC) power. Since it was anticipated that the required battery pack would be a major contributor to the overall weight and cost of the guidance unit, highest overall servo efficiency was to be a major goal. Adequate battery power was to be carried to provide normal servo operation for 30 minutes of flight time. Since high peak currents generally contribute to reduced battery/controller/motor efficiency, initial guidelines favored supplying the required watt-hours of power with higher voltage, lower current battery packs.

c. Weight and Cost. - Wherever available options allowed weight or cost to be a consideration, the component with the least weight or cost was placed in the favored position.

d. Motor Controllers. - The search for motors and motor controllers suitable for battery operation revealed that true DC controllers were generally not readily available as off-the-shelf components. In general, industrial DC motor controllers were readily available but fell into two categories: those used for machine tool control which used 60 Hz line voltage as primary power or those used in electric vehicles for propulsion and/or lift control.

The machine tool controls are designed for 60 Hz line voltage and SCR switches which use the alternating line voltage as an essential input to turn off the SCR's. Only one manufacturer, Control Systems Research, was found which produced an essentially "off-the-shelf" DC motor controller for machine tool control. A second manufacturer, Inland Motors, indicated they had a machine tool motor controller which was modifiable to battery operation but at a higher cost.

Several motor speed controllers designed for the control of traction motors were found which had more than ample capacity for this application. In all cases, these speed controllers were designed for use with wound field motors and used mechanical contactors for rotation reversals. Since mechanical contactors are not suitable for a rapidly reversing position servo system, these speed controllers can be used only if used in pairs with a split field type of traction motor. Although this system requires two controllers, the lower cost of the controllers and the normally lower cost of the traction type DC motor allowed this system to remain a contender for this application if power consumption is not excessive.

e. Motors. - Four classifications of DC motors could be used for this application:

- Permanent magnet servo motors
- Permanent magnet general purpose
- Wound series field general purpose
- Wound series field traction motors.

All four of the above choices provide the required high stalled and starting torques needed for this application. In general, the permanent magnet motors are lighter in weight, more efficient and have a higher cost than the wound field motors. Of the two permanent magnet motors, the servo motors designed especially for machine tool control are most expensive but easiest to apply and also are normally complete with integral tachometer. The general purpose permanent magnet motor is less expensive, less efficient, and does not include a tachometer, which requires that rate feedback must be supplied by external attachments.

The wound series field motors are less expensive, heavier and less efficient than the permanent magnet motors. Another disadvantage is that two separate speed controllers are required to provide electronic bidirectional speed control, and the motor must be wound with a non-"off-the-shelf"

split series field. Regardless of the disadvantages, this system may be considered cost competitive with the permanent magnet motors.

The "off-the-shelf" speed controllers for the wound field motors are generally limited to battery voltages of 48 Vdc or less which places these motors in the lower voltage, higher current category. This higher current requirement can result in a reduced controller/motor efficiency.

In the integral horsepower size, wound field motors required by the large load canopy (approximately 2.5 HP) are not available "off-the-shelf" in the strict sense of the word. Normal industry practice is to supply a motor specially wound to meet all specific electrical and mechanical requirements assembled from mechanical components which are indeed "off-the-shelf". The nearest "off-the-shelf" motors are the more expensive machine tool permanent magnet servo motors which are precision, thoroughly specified motors which may represent over-design for a servo with modest accuracy requirements.

f. Battery Requirements. - Adequate battery power must be included to provide up to 30 minutes of operating time for the canopy guidance unit. To assure that the motor does not drain the battery prior to touchdown, the battery AH rating should be equal to at least the loaded run current of the servo motor. Additional battery capacity would be desirable to provide additional margin, however, larger batteries can increase the weight and cost of the power source beyond practical values.

Batteries suitable for this application must be capable of supplying peak currents in excess of 100 amp, must be rechargeable in excess of 100 cycles, must operate in any orientation, must survive tumbling, must have low internal resistance, must have good shelf life, should be lightweight, and should be low cost.

After considering the tradeoffs between sealed lead acid, sealed nickel cadmium and silver zinc batteries, only sealed lead acid cells were found to be practical. The high cost of sealed nickel cadmium and silver zinc batteries was the basic reason for eliminating them as contenders.

g. Gear Reducer. - The function of the gear reducer is to provide efficient coupling between the motor shaft and the steering drum shaft. Since reduction gears are generally high cost items and contribute a loss of efficiency, the possibility of direct drive between the motor shaft and the

steering drum was investigated briefly. The results indicated that this concept resulted in excessive motor size accompanied by excessive battery currents.

The options available in the selection of the type of gear reducers are generally limited to a reducer fabricated with helical gears, spur gears, or one using a worm and worm gear reducer. All speed reducers reduce efficiency as the gear ratio increases which requires that one of the goals during the servo design should be to keep the gear ratio as low as practical. Also, a reducer using a helical or spur gear is inherently more efficient than one using the worm and worm gear drive which places them in a favored position when battery requirement is considered. However, helical gear reducers are generally more expensive, larger, and heavier than a worm gear reducer capable of producing the same output torque. Since worm gear reducers can produce acceptable efficiencies at low gear ratios, the best compromise in servo drive design is to use a motor designed for high efficiency at low RPM and a low gear ratio worm gear reducer.

The worm gear does have one advantage over the spur gear which may equalize the efficiency differential between it and the spur gear. The worm gear tends to be self-locking which reduces the motor torque required to maintain the steering drum at a fixed position. With the spur or helical gear reducer, the load torque placed upon the steering drum is transferred more efficiently back to the motor which is then required to apply counter-torque to hold the load stationary. An exact evaluation of which type of gearing will result in the least amount of battery power consumption during a typical cargo drop cannot be made due to insufficient data. Engineering judgment indicates either type of gearing will provide satisfactory performance. This places worm gearing in the favored position primarily due to cost, size, and weight. The use of the self-locking worm and worm gear speed reducer is mandatory if a servo is used to apply proportional braking to the canopy since proportional braking requires the servo to operate under load for long periods of time.

2.2.2.5.3.2 Large Load Servo

2.2.2.5.3.2.1 Performance Requirements. - The following performance requirements for the control actuators for the 15,000 pound load canopy were established as:

Maximum Deflection:	2 meters
Maximum Rate:	0.5 meters/sec (19.6 in/sec)
Control Force:	750 pounds
Duty Cycle:	Occasional full deflections either side lasting 20 ±10 seconds with continued small corrections.

Preliminary output horsepower required was determined to be approximately:

$$HP = \frac{750 \times 1.64}{550} = 2.24 \text{ HP}$$

An estimate of the peak electrical power required to provide this HP, neglecting efficiency, will be roughly

$$2.24 \times 746 \text{ or } 1671 \text{ W}$$

Considering voltage current tradeoffs, available batteries, controllers, and standard DC motors, a battery potential of 96 Vdc was chosen as a practicable optimum. This battery potential, assuming a 50% efficient system, will require a peak current of

$$\frac{1671}{96 \times 9.5} \text{ or } 34.8 \text{ amps}$$

The 34.8 amps is a practicable current which can be controlled using available controllers, and it is also compatible with existing batteries.

An accurate scenario of a typical flight is not available; the total battery capacity must be estimated. Assuming that the maximum flight duration need never exceed 30 minutes, and a worst case continuously running motor, the minimum ampere hour capacity of the battery must be 34.8/2 or 17.4 AH. Considering the cold temperature reduced performance of the battery, a 25 AH battery was defined as the best compromise between reserve power, cost, and weight.

Since the search for batteries suitable for this application resulted in the selection of batteries very near the estimated ampere hour capacity requirement, wound field motors were eliminated as candidates for the large canopy application. This decision was made primarily due to the reduced efficiency of the wound field motor and the need to maintain battery power safety margins at the highest practicable level. The duty cycle of a motor is estimated to be approximately 20 to 30 percent during an actual cargo drop, which increases the energy margin. However, the energy that a battery can deliver is subject to numerous variables, such as temperature, state of charge, battery condition, etc. Increasing the AH capacity of the battery to allow the use of a less expensive motor is not cost effective. Consequently, only permanent magnet motors were considered for this application.

The decision to use a permanent magnet motor determines the selection of a motor speed controller, since the CSR model NC 421 controller is the only known motor controller which combines the required performance characteristics with the lowest cost.

2.2.2.5.3.2.2 Gear Motor Selection. - Factors which influence the selection of a motor for this application are:

a. Permanent magnet motor required
b. Efficiency

c. Cost
d. Weight
e. Compatibility with gear head
f. Compatibility with controller
g. Compatibility with 96V battery.

A summary of the characteristics of motors considered for the large load application is shown in table 3. As a group, motors produced for machine tool control were directly applicable and most nearly met the "off-the-shelf" requirement. Of this type, the Peerless 5680-PF4K7711 was preferred because of its efficiency, cost, and weight.

All the motors shown in table 3, when combined with the proper gear ratio gearhead, are suitable for this application. Thus, the final selection can be based upon cost, weight, and loaded motor current. The loaded motor current is defined as the motor current required to retract the 750 pound load at a maximum rate of 20 inches per second, and it provides a figure of merit for comparing the motor/gearhead combination.

As an example, the Peerless 5680-PFK7711 motor, when under load and connected to a 90 Vdc power source, will rotate at approximately 916 RPM or 15.27 RPS. Since the steering drum rotation is required to be approximately 1 RPS, a speed reducer with a standard gear reduction of 15:1 was selected as the nearest standard ratio. When combined with this motor, the gear reducer output shaft will rotate at 15.27 ÷15 or 1.018 RPS.

If the steering drum rotates at 1.018 RPS and if the line displacement rate is 19.6 inches per second, the drum circumference must be 19.6 ÷1.018 or 19.25 inches (diameter = 6.12, radius = 3.06). To pull the 750 pound load, the gear box must provide an output torque of 750 x 3.06 or 2299 inch pounds.

Referring to the Winsmith Wingear catalog, the 300 MWT-15:1 speed reducer is capable of providing an output torque up to 2566 inch pounds with an input RPM of 900. The overhanging load rating of 1332 pounds is adequate to meet the 750 pound application requirement. The efficiency of this unit is rated at 2.44 ÷2.88 or 85%. The torque required at the motor shaft input to the gear reducer will then be 2299 ÷(15 x 0.85) or 181 inch pounds (15 foot pounds). The motor current required to produce this torque, neglecting friction losses and damping constant, is then approximately 181/7.29 or 24.8 amps. (This value is compatible with the continuous current rating of the NC421 controller.)

Returning to the steering drum diameter requirements for this motor, the 19.25-inch circumference requires that ±4.08 turns of the drum are needed to displace the required two meters (78.7 inches) of steering cord. The ±4.08 turns is compatible with the ±5 turn limitation placed upon the drum by the 10 turn feedback potentiometer.

Table 3. Motor Candidates - Large Load Servo

Permanent magnet 2.5 HP	PMI MF19	PMI MF26	PMI MF23	Peerless 5680 DF4K7710	Peerless 5680 DF47711	Peerless 5680 DF47714	Peerless 5610 PPM56D62 K8598	Inland TT2953A	Applied motors SR5324-2212
Price (Quantity) 1	$507	873	760	755	855	855	605	903	236
10	$498	873	735	589	667	667	556	756	198
100	$457	785	680	498	564	564	423	621	160
Rated H.P.	1.3	3.9	2.7	---	---	---	1.0	1.6	1.0
Weight (pounds)	?	65	55	42	59	59	51	21.7	34
Length (inches)	5.5	7	4.5	10.5	12.5	12.5	14.5	12.6	11.8
Diameter (inches)	9	12.5	10.5	7.5	7.5	7.5	6.5	4.25	7.0
Torque Sensitivity (pound inches per amperes)	2.31	3.87	4.4	3.13	7.29	3.08	4.118	4.65	3.791
Back EMF Constant (V/KRPM)	27.3	45	49.7	37.1	88.2	36.44	48.69	53.95	45
DC Resistance (ohms)	9.56	0.28	0.7	0.196	0.37	0.07	0.302	0.393	0.7
Inductance (mH)	negl.*	negl.*	negl.*	9.88	1.7	0.32	2.643	1.6	5.1
Loaded RPM	2649	1843	1445	2290	916	2421	1687	1490	1533
Nearest Gear Ratio	40:1	30:1	20:1	40:1	15:1	40:1	30:1	20:1	30:1
Loaded Gearhead RPS	1.104	1.024	1.20	0.954	1.018	1.008	0.937	0.83	0.85
Drum Diameter (inches)	5.65	6.09	5.18	6.53	6.13	6.18	6.66	7.53	7.33
Gearhead Output Torque (pound inches)	2119	2285	1943	2452	2299	2319	2496	2825	2747
Loaded Motor Torque (pound inches)	71.6	97.6	114.3	82.8	181	78.35	106.7	110.8	107.7
Loaded Motor Current (amps)	31.0	25.2	25.9	26.5	24.82	25.4	25.9	24.3	28.4

*Requires 1 mH Inductor

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The Peerless line of servo motors is available without a tachometer at a cost saving of $160. Since precise speed regulation is not a requirement for this servo, it is recommended that the motors be purchased without a tachometer. Rate feedback required to produce a stable servo can be derived by electronic means by simple differentiation of the position feedback potentiometer output. The electronic circuits required to derive the rate feedback will add less than $10 to the cost of the summing amplifier.

Two general purpose permanent magnet motors were found (Peerless 5610 and Applied Motors SRS-324). These motors are lower in price than the servo-type motors but their true availability is questionable. It was found that manufacturers of general purpose motors showed little enthusiasm for supplying motors in the limited quantities required for this application. Final selection of a suitable motor must be based upon availability at the time of purchase.

2.2.2.5.3.2.3 Battery Power Pack. - The search for sealed lead acid batteries suitable for the large load servo resulted in the selection of three possible contenders:

- Gates 25AH (2V cell)
- Eagle Picher CF12V30 (12V battery)
- YUASA NP24-12 (12V battery).

Since the Gates 25AH is a single 2V cell, the cost of packaging these cells to make up the required 96V battery must be added to the purchase price of the individual cells. The packaging labor and material costs make these batteries the most expensive of the three. However, since the intercell connections can be especially designed for this high current application, a battery using these cells would provide the most efficient battery of the three. Another asset of this battery is that a single cell could be replaced if a cell failure should occur. It is difficult to assess how much weight should be placed on this asset since a cell failure may soon be followed by a second cell failure due to common age and usage.

Comparing the published data on the Eagle Picher CF12V30 and the YUASA NP24-12 (see table 4) indicates that either battery will perform satisfactorily for this application. The cost and weight of the YUASA NP24-12 and the fact that it is available with high current bolt connectors places this battery in the preferred position.

2.2.2.5.3.2.4 Large Payload Servo Cost Summary. - The cost of the major components of the servo system using the Peerless 5680-PF4-K7711 motor can be estimated as following:

Table 4. Major Battery Characteristics

Cell	1-hour A/H	20-hour A/H	96V weight	96V volume	96V cost
Gates 25 AH	20 (50%)	25	176 pounds plus package	2177.9 in^3	915.84
Eagle Picher	16 (75%)	28	190 pounds	2177.9 in^3	612.40
YUASA	14.4 (75%)	24	144 pounds	1774 in^3	466.56

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	Quantity 1	Quantity 10	Quantity 100
Motor	$ 855	$ 667	$ 564
Speed Reducer	238	185	128
Motor Controller	528	480	390
Summing Amplifier	100	90	70
Position Potentiometer	10	9	8
Batteries	466	386	351
	$2,197	$1,817	$1,511

2.2.2.5.3.3 Medium Payload Servo

2.2.2.5.3.3.1 Performance Requirements. - The following performance requirements for the control line actuators for the 2000 pound load canopy were established:

Maximum Deflection:	1.2 meters
Maximum Rate:	0.3 meters per second
Control Force:	150 pounds
Duty Cycle:	Occasional full deflections either side lasting 20 ±10 seconds with continual small deflections

2.2.2.5.3.3.2 Motor Selection. - From the above requirements, preliminary output horsepower was determined to be approximately:

$$HP = \frac{150 \times 1}{550} = 0.27 \ HP$$

An estimate of peak electrical power required to provide this level of HP, neglecting efficiency, will be roughly

$$0.27 \times 746 \text{ or } 200 \ W$$

Assuming a motor efficiency of 80 percent, a gearhead efficiency of 80 percent and a motor controller efficiency of 75 percent, the peak electrical power required from the batteries will be

$$\frac{200}{0.8 \times 0.8 \times 0.75} = 417 \ \text{Watts}$$

To allow the motor to run continuously at the specified HP output requires the following current:

Battery	Peak Current	1/2-Hour Capacity
24V	17.37	8.7AH
36V	11.58	5.8
48V	8.69	4.34AH
96V	4.34	2.17AH

In order to minimize battery drain, only permanent magnet type motors were considered for this application. A review of manufacturer's catalogs revealed numerous permanent magnet motors in the desired 1/3 to 1/2 HP range capable of operating from the above battery voltages. When reviewing available motor controllers suitable for use with batteries, no "off-the-shelf" reversing motor controls were found for voltages less than 48 Vdc. Since the moderate HP requirements did not justify the number of batteries required to provide 96V, a motor/controller combination using a 48 Vdc power source was preferred.

Discussions with manufacturers of the lower cost general purpose motors revealed that motors wound with 48V rotors could be produced as easily as their "standard" 24V rotors. However, no manufacturer showed any interest in providing the correct rotor when they were informed of the low quantity requirements for this application. As a result, candidate motors for this application were limited to high performance motors designed for machine tool servo systems. All motors considered for use were selected based upon data published in current manufacturer's catalogs.

A listing of motors suitable for this application is given in table 5. Based upon the data shown, the motor with the best cost/weight/efficiency rating would be the model E4965-2-02 available from AMETEK/LAMB. This motor is available at a base price of $125.00.

Table 5. Motor Candidates - Medium Load Servo

Permanent magnet 1/2 HP	PM1 U16M4	Owosso Redmond PR4Y00Q	Inland TT2950-C	Ametek 6"-02	Torque MH5130-001-A
Price 1	$338	100	550	125	351
(Quantity) 10	$315	100	515	125	262
100	$219	100	460	72	198
Rated H.P.	1/3	1/2	1	1/2	1/2
Weight (pounds)	16.5	?	16.5	9.2	19
Length (inches)	2.56	7.03	8.25	6"	8"
Diameter (inches)	7.37	4	4.25	4"	5"
Torque Sensitivity (pound inches per amperes)	1.95	1.098	2.16	1.875	1.125
Back EMF Constant (V/KRPM)	23	16.5	25.5	22.2	21.5
DC Resistance (ohms)	0.89	0.402	0.712	0.58	0.32
Inductance (mH)	neg	?	1.8	3.07	?
Loaded RPM	1870	2697	1700	1995	2140
Nearest Gear Ratio	30:1	40	20:1	30:1	30:1
Loaded Gear Head RPS	1.04	1.12	0.944	1.108	1.19
Drum Diameter (inches)	3.62	3.34	3.98	3.39	3.16
Gearhead Output Torque (pound inches)	271	250.7	298	254	236
Loaded Motor Torque (pound inches)	12.7	9.5	14.0	11.9	11.1
Loaded Motor Current (amps)	6.53	8.65	6.48	6.36	6.14

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The gear reducer required by this motor must have a 20:1 reduction ratio. A suitable gear reducer, Model 175-MWT-30:1, is available from Winsmith Division of VMC Industries. The cost of this unit is $134.00 each and $87.50 in quantities of 100.

Selection of a suitable motor controller is limited to the Control Systems Research, Inc., Model NC104B if an off-the-shelf controller is desired. The base price of this controller is $730.00. In 100 quantities, this controller is priced at $481.00.

2.2.2.5.3.3.3 Battery Power Pack. - As shown in table 5, the motor selected for the 2000 pound load canopy is expected to require 6 amps of current at maximum load and rate. Assuming a 30 percent duty cycle for the motor, the average current requirements will be 1.8 amps. A flight which lasts 30 minutes then requires 0.9 AH of battery capacity. Four Yuasa NP6-12, 12 V, 6 AH sealed lead acid batteries will provide adequate reserve power. The cost of these batteries, in sets of four, is:

1 set	$100.88
10 sets	83.40
100 sets	75.80

2.2.2.5.3.3.4 Servo Cost Summary. - The cost of the servo system for the 2000 pound capacity canopy using the selected components is estimated as follows:

	Quantity		
	1	10	100
Motor	\$ 125.00	\$ 125.00	\$ 72.00
Speed Reducer	134.00	126.00	87.50
Motor Controller	730.00	657.00	481.00
Summing Amplifier	100.00	90.00	70.00
Position Potentiometer	10.00	9.00	8.00
Battery	101.00	84.00	76.00
	\$1,200.00	\$1,091.00	\$795.00

The major cost item in the above list is the motor controller. Assuming that the quantity requirements would justify the engineering costs, a less expensive controller could be made available by modifying one of the CSR NC400 series controllers for use at the 48 V battery potential.

2.2.2.5.3.4 Small Payload Servo

2.2.2.5.3.4.1 Performance Requirement. - The following performance requirements for the control line actuators for the 500 pound load canopy were established:

Maximum Deflection:	24 inches
Maximum Rate:	6 inches per second
Control Force:	25 pounds
Duty Cycle:	Occasional full deflections either side lasting 20 ±10 seconds with continued small deflections.

From the above requirements, preliminary output horsepower was determined to be

$$HP = \frac{25 \times 0.5}{550} = 0.023 \text{ HP}$$

An estimate of peak electrical power required to provide this HP, neglecting efficiency, will be

$$0.023 \times 746 \text{ or } 17.2 \text{ watts}$$

Assuming a motor efficiency of 80 percent, a gearhead efficiency of 75 percent and a motor controller efficiency of 75 percent, the peak electrical power required from the batteries will be

$$\frac{17.2}{0.75 \times 0.75 \times 0.8} = 38.2 \text{ watts}$$

The relatively low power required by the light load canopy provides a servo option not available to the higher horsepower units. The servo efficiency need not be given the critical weighting required by the higher H.P. servos since increasing the battery capacity to compensate for reduced efficiency does not greatly impact overall cost and weight.

Since the smaller servo need not be as efficient, the motor controller may be either the efficient pulse width modulated system or the less efficient linear amplifier.

If a linear motor controller is used, two options are available regarding its configuration; a single supply, or a dual supply configuration. In the single supply configuration, the controller uses a bridge output which allows nearly the full battery potential to be placed across the motor. The dual supply configuration uses two batteries connected in series as the power supply with one motor lead connected to the common connection between the batteries. The motor run rate and reversing is then controlled by the controller's connecting the input motor lead to either the positive or the negative battery.

Considering efficiency alone, the pulse width modulated controller is preferred since full battery voltage appears across the motor and minimum power is dissipated by the saturated drive transistors. The power dissipated by the output transistors approximates a constant percentage (10 to 20 percent) of the motor's power output. At maximum motor speeds, the linear amplifier is as efficient as the pulse type controller. However, at low motor speeds, the linear driver dissipates many times the power being delivered by the motor. This wasted power must be obtained from larger batteries.

Comparing the two types of linear drivers, the single-supply bridge output configuration is slightly more efficient than the two-supply configuration. The single-supply linear driver also is preferred over the dual-supply driver since motor current is supplied equally by all batteries. A dual-supply driver and a spur type gear motor would be a poor combination for a canopy servo since, in the presence of a wind, only one battery would be discharged during the majority of the flight. If a self-locking worm type speed reducer is used, the battery energy consumed will be better balanced but still unequal. This uneven battery drain would require that the battery capacity be doubled relative to that required by the single-supply controller in order to assure adequate power to complete the flight.

Although the dual-supply linear driver is the least desirable, it may prove to be the most cost effective when only "off-the-shelf" components are considered. A battery potential of 24V is optimum for the light load guidance system and two 12V batteries would be used to provide this potential. The resulting ±12V dual supply opens the possibility of using lower cost 12V automotive-oriented DC gear motors in this application.

2.2.2.5.3.4.2 Gearmotor Selection. - Considering the size of the motor required for this application, it is most practical to purchase the motor and speed reducer as a complete assembly. The most readily available off-the-shelf gear motor is the Globe Model 102A181-10 which was used in the AGU-500 Canopy Guidance Unit. This unit is a relatively expensive premium quality gearmotor which was used primarily because it could be purchased directly from the distributor's stock.

Lower cost units, such as the PMI U12FG gearmotors are available but require longer lead times. Assuming that adequate lead time is available, other suitable gearmotors are available as shown in table 6. Undoubtedly, others exist but were not located during this study.

The most cost effective of the gearmotors shown in table 6 are those manufactured by the Von Weise Company. However, all are standard only with 12 Vdc motors. Considering only spur gear types, the VW-88 would be favored over the VW-83 because of its more rugged construction. At slightly more cost, the VW-33 combines the benefits of a worm drive with the efficiency of spur gears.

Table 6. Gearmotor Candidates - Small Load Servo

Permanent magnet gear motor 1/30th HP	Globe 102A181-10	PMT U12FG	RAE 5303	RAE 5317	Von Weise VW-83 ACB3	Von Weise VW-88 AGB2	Von Weise VW-33 AKB2
Price (Quantity) 1	$468	179	172	172	45	61	86
10	$360	179	220	220	35	49	70
100	$244	145	100	100	18	39	56
Rated Motor Voltage	27V	24V	12V	12V	12V	12V	12V
Rated H.P.	0.033	0.066	0.119	0.05	0.033	0.05	0.05
Gear Ratio	170:1	100:1	58:1	60:1	149:1	128:1	70:1
Length (inches)	4.47	3.75	8.12	11.5	5-1/2	7-1/2	8-1/2
Diameter (inches)	1-7/8 x 1-7/8	6	4 sq.	3.5	3-1/2 sq.	4-5/8	6-1/2
Gear Type	Spur	Spur	Spur	Worm	Spur	Spur	Hybrid
Loaded RPS Out	30	30	34	32	35.1	27.7	29.4
Loaded Motor Current	1.4A	2.35 Requires Inductor	3.5	8	2.6	2.8	2.31

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If the off-the-shelf rule is not adhered to, these gearmotors could be supplied with 24 Vdc rotors at increased cost. The cost increase to obtain the 24 Vdc rotors would be balanced by eliminating the extra battery required by the reduced efficiency of the 12V motor.

2.2.2.5.3.4.3 Motor Controllers. - Three motor controllers suitable for the light load canopy system were found.

In the pulse width modulation category, the motor driver built by Magnavox for the AGU-500 Airborne Guidance unit, is suitable for motors with 24V rotors only. This limits its use to the Globe 102A'81-10 gearmotor or the PMI U12FG (with series choke) only. This motor driver is available in prototype configuration at a cost of $200.

In the linear driver category, Torque Systems, Inc. Model DA223 driver is suitable for the above 24V motors. This driver is a single-supply driver and would provide balanced battery drain. The cost of this unit is also approximately $200.

Torque Systems also manufactures a dual-supply motor driver, their Model PA-111, which is suitable for driving the listed 12 Vdc motors. The use of this driver would require larger AH rating batteries, but its cost of $90 each balances the cost of the additional batteries.

Assuming that the quantities involved justified the engineering costs, the Magnavox pulse width modulated driver could be provided specifically adapted for use with the 12 Vdc motors. Since this results in both lower motor costs and reduced battery cost, it is worthy of consideration.

2.2.2.5.3.4.4 Small Payload Servo Cost Summary. - A summary of the cost of the selected major components, including battery for the light load canopy, follows.

24V System

	Quantity		
	1	10	100
PMI U12FG Gear Motor	$179	$179	$145
Inductor	15	14	12
Motor Controller (Magnavox)	200	150	125
Summing Amplifier (Magnavox)	100	90	70
Position Potentiometer	10	9	8
Battery (Yuasa NP6-12)	50	42	38
	$554	$484	$398

12V System

	Quantity 1	10	100
Von Weise VW33 Gearmotor	$ 86	$ 70	$ 56
Motor Controller (Torque PA111)	90	84	63
Summing Amplifier (Magnavox)	100	90	70
Position Pot	10	9	8
Battery (Yuasa NP6-12)	100	84	76
	$386	$337	$273

2.2.2.5.3.5 RFI Considerations. - It is expected the DC motor and the pulse-width modulated motor controller will provide radio frequency interference problems. A brief study on the cost of RFI suppression revealed that filters capable of suppressing the RFI generated by the motor and motor driver approaches the cost of the motors themselves. Since the cost of high current RFI suppression is excessive and since it is doubtful that the RFI could be totally controlled, it appears that a better procedure would be to attempt to contain the RFI rather than suppress it.

To successfully contain the radio frequency interference, the DC motor, the motor controller, and the batteries required for motor power should be placed in a common RF tight compartment and interconnected to avoid skin currents. The control signals required to provide steering control to the motor controller can then enter this compartment by means of relatively inexpensive low power RFI filters.

The DC power required to operate the Antenna Lobing Switch, the UHF Receiver and the low power steering circuits must be provided by separate low power, low voltage batteries. Two 12V, 1 AH batteries will be adequate. These batteries are available at a cost of approximately $14.00 each.

2.2.3 Ground Beacon

2.2.3.1 General. - The ground based radio frequency source required to provide the homing signal for the minimum cost radial homing guidance unit has very modest requirements. The minimum cost radial homing guidance unit as described in the preceding paragraphs will home on any RF source which is tuned to the receiver frequency.

2.2.3.2 Modulation Requirements. - The beacon transmitter may be unmodulated CW or it may contain modulation of any type. The only precaution required when selecting the modulation signal is that the modulation should not contain continuous low frequency components near the guidance package antenna lobing frequencies (60 to 100 Hz). Amplitude modulation at the antenna lobing frequency, when hetrodyned with the lobing frequency, will produce very low frequency components which, when summed with the

steering signal, will cause steering offset or an oscillatory ground path. The presence of occasional transients at these frequencies is acceptable provided their duration and repetition rate is too short to cause appreciable disturbance to the steering servo (1 second or less).

2.2.3.3 Power Output Requirements. - To assure that the homing guidance package can acquire the beacon at the maximum specified drop distance, the beacon transmitter should transmit a minimum of 400 milliwatts of RF power.

2.2.3.4 Available Equipment. - Any available UHF transmitter capable of being tuned to the frequency required by the airborne guidance unit and having an RF power output of 400 milliwatts or more may serve as a ground beacon when only radial homing is required.

The BCT-360 Beacon/Controller Transmitter manufactured by Magnavox as a beacon for the AGU-500 Airdrop Guidance Unit is suitable for use as the beacon for the minimum cost radial homing guidance unit. A description of this unit may be found in Appendix B. This transmitter also provides manual control capability. A "beacon only" version of the BCT-360 could be produced at approximately one-half the cost and one-third the size of the present BCT-360.

The present cost of the BCT-360 Beacon/Controller Transmitter is: quantity 1 - $524; quantity 10 - $419; and quantity 100 - $314. At the present time, the unit is available in prototype configuration only.

2.2.4 Cost Summary

A summary of the estimated cost of the major components of the minimum cost radial homing guidance package is given in table 7.

Since the prices in table 7 reflect the cost of major components only, the cost of integrating them into a completely packaged guidance unit must be added. The packaging and component integration will require non-recurring engineering costs plus additional hardware costs.

To complete the system, the cost of the ground beacon must also be added.

Table 7. Radial Homing Minimum-Cost Summary

	1	10	100
500 Pound Load			
Antenna	$ 10	$ 8	$ 6
Antenna Lobing Switch	142	114	86
UHF Receiver	178	142	106
Synchronous Detector	50	40	30
Servo System and Battery	554	484	398
	$ 934	$ 788	$ 626
2000 Pound Load			
Antenna	$ 10	$ 8	$ 6
Antenna Lobing Switch	142	114	86
UHF Receiver	178	142	106
Synchronous Detector	50	40	30
Servo System and Battery	1200	1091	795
Battery Pack (Electronics)	50	46	38
	$1630	$1441	$1061
15,000 Pound Load			
Antenna	$ 10	$ 8	$ 6
Antenna Lobing Switch	142	114	86
UHF Receiver	178	142	106
Synchronous Detector	50	40	30
Servo System and Battery	2197	1817	1511
Battery Pack (Electronics)	50	46	38
	$2627	$2164	$1777

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2.3 Manual Control Options

2.3.1 Manual Steering Option

The addition of manual steering capability to the minimum cost radial homing guidance unit shown in figure 2 requires the replacement of the synchronous detector (figure 4) with a Control Decoder module similar to the one used in the AGU-500, Airborne Guidance Unit. Also the BCT-360 Beacon/Controller Transmitter must be used as the ground beacon.

If manual pitch control is not required, the only change to the basic block diagram shown in figure 2 is that the function labeled, "Synchronous Detector" be replaced by a functional block labeled Control Decoder. A description of the AGU-500 Control Decoder is included in Appendix B.

The costs of adding manual steering control are increases of approximately $100 for the control decoder module and approximately $574 for the BCT-360 Beacon/Controller Transmitter. Only minor modifications to each unit are required to delete the manual flare mode.

The capability to selectively address individual guidance units during manual control is inherent in the BCT-360/Control Decoder combination and this feature would normally be retained.

2.3.2 Manual Glide Ratio Control

2.3.2.1 General. - The addition of remote pitch control adds complexity and cost to the basic radial homing guidance unit, primarily because it requires the addition of a second motor, motor controller, speed reducer, line actuator, and additional low power circuitry for actuation logic and control.

An initial consideration was given to obtaining pitch control through the use of the main steering motor and changing its function from steering to flare by means of appropriate gearing and clutches. It was found that the cost of the required gearing and clutches approximated the cost of a motor/gearbox assembly dedicated to pitch control alone. Since the presence of a second motor/gearbox assembly increases the potential flexibility and control options, further consideration of the use of clutches for flare control was eliminated. The presence of the second motor required for pitch control also adds several options to the steering function, since one or both motors can be used to provide the steering function.

The decision to provide either single or dual motor steering depends primarily upon the type of pitch control required by the specific canopy. If pitch control of the canopy can be accomplished by retracting both steering lines, then two motor steering is the preferred method. If pitch control cannot be accomplished by retracting both steering lines, both must be accomplished by retracting a line(s) dedicated for pitch control only, then single motor steering must be used.

Two motor steering, where each motor controls only one steering line exhibits several advantages compared to single motor steering. Single motor steering requires payout of loose line from one drum while the other drum is retracting its line, which requires special design considerations to prevent loose line entanglement. Additional difficulty is experienced in drum placement and line storage facilities to ensure symmetrical exit of the steering line from the guidance package. The presence of a third drum and motor for pitch actuation adds mechanical complexity.

When dual motor steering is used the motors, gearheads, and drums can be placed side-by-side, allowing a symmetrical and inherently less complex mechanical design. Loose steering line does not occur and consequently, the possibility of loose line entanglement is eliminated.

The one condition when loose steering line can be used to advantage is when the canopy/cargo package is first deployed. To prevent the opening shock from being transfered directly to the steering drums, the canopy control lines are anchored to the package support lugs, and a second line from the steering drum is connected in parallel to the canopy control line. In a single motor steering system, there must be no slack in the lines from the steering drum to prevent a large dead zone near neutral (straight ahead flight). This condition increases the possibility that the opening shock may be applied directly to the steering drums. The two motor steering system allows a small amount of extra line to be stored on the drums to be manually extended during canopy packing. Since slack exists in the steering lines when the assembly is deployed, the opening shock can be applied only to the guidance package support lugs. After deployment, the steering servos will automatically retract the excess steering line when they are energized.

When pitch control must be applied via lines dedicated to pitch control only, the single motor steering method must be used, or a three motor design accepted, regardless of the increased complexity of the mechanical design. Single motor steering has the advantage of simplifying the electronics required for steering control, although the cost saving is minor.

Regardless of whether single motor or two motor steering is used, several optional methods of pitch control are available which can be used with either system. Since the options are implemented in the electronics provided by the non-off-the-shelf interface modules between the receiver and the servo controllers, the option which most nearly meets the requirements of the application can be selected with little effect on the overall cost of the guidance system. The following pitch control options are submitted for consideration:

(1) Centered Steering - Step Input Pitch Control
(2) Proportional Pitch Control with Manual Steering
(3) Proportional Pitch Control with Radial Homing

2.3.2.2 Centered Steering with Step Input Pitch Control. - When this method of control is implemented, a pitch command from the ground controller causes the steering to return to neutral and the pitch control lines are pulled to a fixed, fully retracted position. If two motor steering is used, the two motors equalize the line deflections then pull both steering lines to the fixed fully retracted position. The AGU-500 uses this control method.

This control method is normally used if pitch control is needed only to reduce the forward velocity of the canopy just prior to touchdown, and is not suitable for adjusting the forward velocity of the canopy during normal flight.

2.3.2.3 Proportional Pitch Control with Manual Steering. - When proportional pitch control is used, the operator can command any desired amount of retraction of the flare lines. Proportional pitch control provides the operator with a degree of control over the ratio of forward velocity to vertical velocity, and, consequently, the canopy's approach glide slope. Pitch control allows the operator to optimize not only the canopy heading, but also its approach elevation angle.

Assuming that it is unnecessary to steer to avoid physical obstructions, the technique which provides minimum impact velocity is steering the airdrop to a position directly downwind from the target site. One must also position the incoming cargo so that its elevation angle remains constant during its approach. An observed increasing elevation angle indicates that the target site will be overflown, while a decreasing angle indicates that the cargo will touch down short of the desired impact point.

The specific elevation angle required for a minimum miss upwind approach is, of course, a function of the existing wind velocity. Since existing wind velocities will not be accurately known by the operator on the ground, the optimum elevation angle cannot be predicted, except that it lies between vertical and the normal no wind glide slope of the canopy. However, in the absence of more sophisticated equipment, the ground observer can determine if the existing approach speed is excessive or insufficient by determining whether the elevation angle is increasing or decreasing.

Proportional pitch control provides the operator with the means to vary the forward velocity of the canopy as required, until a relatively constant elevation angle is maintained. Successful application of this procedure will require more than minimal skill level on the part of the operator. Miss distances using this procedure will probably not be less than those obtained if the canopy is allowed to impact using radial homing alone. However, if manual steering is required to assure into-the-wind and, consequently, lower velocity landings, forward velocity modulation using proportional pitch control should result in reduced miss distances.

Adding proportional Pitch Control to the BCT-360 Beacon Controller Transmitter would increase the material costs by approximately $30 in addition to non-recurring engineering costs.

The addition of proportional pitch control capability to the Airborne Guidance Unit will increase the cost of the Control Decoder module by approximately $30 compared to its cost to provide manual steering and step pitch control.

When a two motor steering method is used, proportional pitch control is implemented by summing the desired flare position to the manual steering signal to cause the line retraction to be proportional to the steering command plus the desired braking line travel. When single motor steering is used, the steering servo and the pitch servo responses are independent.

Since proportional flare requires that the flare servo must apply torque to the braking lines for extended periods of time, it is essential that the gear reducer between the motor and drum actuator be of the worm and worm gear type, because a gear reducer of the helical or spur gear type would require the application of continuous motor torque which, in turn, would require an unnecessary continuous current drain of the batteries.

2.3.2.4 Proportional Pitch Control with Radial Homing. - This option is similar to the preceding option except that it eliminates the requirement for manual steering by allowing the canopy steering to remain in the radial homing mode. Radial homing during the final approach provides automatic closed loop steering which enables the operator to concentrate upon adjusting the glide slope to the desired angle. It has been found that wind variables (which occur as the canopy approaches the ground) cause course changes which must be corrected by the operator when steering manually. The time required for observation and reaction unavoidably results in a time lag which increases the miss distance. If the final approach to the beacon site can be made with steering provided by automatic radial homing, this time lag is reduced to the response time of the steering servoes.

With the heading of the canopy automatically directed toward the beacon site, and assuming the operator can correctly adjust the approach elevation angle using proportional braking, this option should minimize the average miss distance. To date, Magnavox has not flight-tested a guidance unit containing this capability; the preceding conclusions are based upon engineering judgment alone.

The additional electronic circuitry required to provide proportional pitch control with radial homing is similar to that required to provide proportional pitch control with manual steering.

The most versatile radial homing canopy guidance system could incorporate the benefits of all the preceding modes of operation with a relatively minor impact on the system cost. This is true if the decision has already been made to add manual steering and manual pitch control capability to the basic radial homing system. The digital control word trasmitted by the BCT-360 must be changed from a 16-bit word to a 24-bit word to provide the added bits for the proportional pitch control. The operator option to steer either automatically (radial homing) or manually would remain the same. Proportional pitch control would be available for use at any time. The minimum descent rate must be limited to a value less than that which results in canopy instability. The pushbutton for touchdown flare would remain unchaged to provide automatic centering of steering and full braking flare.

2.3.3 Channel Hop Option

The basic radial homing guidance system previously described is capable of radial homing toward any signal source which radiates at the receiver's frequency. This feature offers the advantage that a special transmitter need not be supplied to the ground personnel if manual control of the canopy is not required. However, this feature provides the undersireable possibility that canopy control may be "stolen" by any transmitter which radiates at the receiver's frequency if the diverting transmitter power at the RF antenna exceeds the beacon transmitter's power.

The RF output of the BCT-360 is less than 400 milliwatts, and may be overridden by nearly any general purpose UHF transmitter. The presence of the decoy signal source will also prevent the guidance unit from properly decoding the BCT-360 manual control commands. The guidance unit will then revert to radial homing and home toward the stronger decoy transmitter.

The only protection from decoy transmitters provided in the basic radial guidance system is that the low power radiated by the BCT-360 makes its presence difficult to detect beyond the local drop zone.

To reduce the possibility of both detection and decoy, a Channel Jump option could be implemented. With this option, the number of fixed frequency channels that could be received by the airborne guidance unit would be increased to five, spaced at 5 to 10 MHz intervals. When operating in the Channel Jump mode and not synchronized by the ground beacon transmitter, the airborne reciever would automatically step through all five channels using a fixed 1, 4, 2, 5, 3 channel selection sequence.

The unsynchronized receiver would dwell at each frequency for five seconds before jumping to the next channel. This would provide the search mode needed to determine the frequency being transmitted by the ground beacon transmitter, and would also ensure that the receiver does not dwell at a fixed frequency decoy transmitter in excess of 20% of the time.

The Channel Jump Option could be implemented in the ground Beacon Controller by changing it from a fixed single frequency transmitter to a five-frequency transmitter whose five frequencies are the same as those of the receiver in the airborne guidance unit. The transmitter would automatically step through the five frequencies using the same 1, 4, 2, 5, 3 channel selection sequence used by the airborne reciever. The transmitter would, however, dwell at each frequency for a period of one second before stepping to the next frequency. This would ensure transmitter frequency/receiver frequency coincidence at least once every 5 seconds.

The control data word transmitted by the ground beacon would contain a "jump command" bit which would be present once each second just prior to the change of the transmitter frequency. This "jump command" bit, when decoded by the airborne guidance unit, would override the normal five second jump interval and cause the receiver frequency to jump to the next frequency synchronously with the transmitter frequency jump. Once synchronized, the receiver would be programmed to self-jump several times at 1.2 second intervals if an interfering transmitter should obliterate the beacon jump command.

The Channel Jump option would reduce the possibility of signal detection because of the short period of time the transmitter dwells at each frequency. The presence of a single frequency decoy transmitter would not prevent the guidance system steering information would be present 80 precent of the time.

The Channel Jump option has never been implemented in hardware at this time. It has been included for consideration only because the basic radial homing guidance unit is vulnerable to being decoyed by higher power transmitters. It is estimated that the additional circuitry required to implement the Channel Jump option would increase the cost of the ground beacon an additional $150. The cost of the airborne guidance unit would also increase by an estimated $175.

2.3.4 Cost Summary with Options

2.3.4.1 Manual Steering Option. - To add manual steering control to the basic radial homing system requires the addition of a Control Decoder Module to the airborne guidance unit and requires the use of the BCT-360 Beacon/Controller Transmitter. The estimated cost of the major components for this system based upon a quantity of one is given in table 8.

2.3.4.2 Manually Controlled Pitch Control Option. - An airborne guidance unit which provides step input pitch control, proportional pitch control either radial or manual steering, and basic radial homing, requires that a Control Decoder Module, a Servo Control Module, and a second control line actuator servo be added to the cost of the basic radial homing system. The estimated cost of the major components for this system is also listed in table 9.

Table 8. Manual Steering Option

	500 pound	2,000 pound	15,000 pound
Basic Radial Homing System	934	1630	2627
Control Decoder Module	100	100	100
BCT-360 Beacon Controller	524	524	524
	$1558	$2254	$3251

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Table 9. Manual Steering With Pitch Control Options

	500 pound	2,000 pound	15,000 pound
Basic Radial Homing System	934	1630	2627
Control Decoder Module	100	100	100
Servo Controller Module	107	107	107
Second Control Line Servo	504	1099	1631
Beacon/Controller Transmitter	574	574	574
	$2219	$3510	$5038

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The totals in table 9 reflect the costs of major components only and do not include the cost of numerous minor components and mechanical assemblies required to integrate the major components into a complete canopy guidance system. Non-recurring engineering costs will also increase the guidance system costs.

2.3.5 Manual Control From Airdrop Aircraft

Effective manual control of an airdrop package from the dropping aircraft requires that data concerning its state be provided to the operator, because the large separation between the aircraft and the airdrop unit renders normal depth perception useless as a control parameter. To improve the performance of the manually guided package requires that the airborne unit provide the operator with its range to the target, its altitude, its airspeed, and the relative bearing to the target. Video data provided by a TV link could also be of value during the terminal phase of the flight. The resolution of a stabilized TV camera has been reported as 1.6 ft^2 at 2200 feet slant range. An unstabilized camera will be cheaper and exhibit poorer resolution.

An airdrop unit configured for Radial Homing with enhanced Manual Control requires no data down-link, only a command up-link. The basic system will require substantial modification to be made suitable for control from an airdrop aircraft, since the feedback data required for this mode of operation are not essential to the normal homing mode, or to the manual control by an operator located at the drop zone impact point, although these data would be of value to him.

The most costly parameter to measure accurately is range. Depending upon the accuracy considered necessary, simpler, less accurate transponders than those of the Mini-Ranger III types could be used. Vega Precision Lagoratories, and others, make a series of transponders designed for use with radars, that operate from S through X Bands. A suitable interrogator is not an "off-the-shelf" item, although its design is straightforward. The use of depression angle/altimeter range determination is a lower cost, less accurate method that may be usable.

Time derivatives of range, altitude and homing deviation angle can be derived at the aircraft terminal if the basic parameters are data-linked to the aircraft. Using range and altitude rates, a manual version of conical homing can be used in which the operator steers to maintain constant the ratio of altitude rate to range rate.

It is also possible to exercise similar control, by the relay of only depression angle data to the aircraft. The operator then steers to maintain the depression angle constant until impact. This approach requires the minimum data transfer, but analysis is needed to determine the performance that can be achieved with the accuracy that this measurement technique can provide.

Table 10 lists the parameters of the data to be relayed, their magnitudes, resolution, and the number of binary bits required to provide the stated resolution.

Table 10. Airdrop Status Relay Parameters

Parameter	Magnitude	Resolution	No. of Bits
Slant Range	15,000 m	1 m	14
Airspeed	0 - 20 m/s	1 m/s	5
Altitude	0 - 30,000 m	10 m	10
Homing Deviation Angle	±360 degrees	1 degree	9
Depression Angle	0 - 90 degrees	1 degree	7

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Additions to the system described in the earilier paragraphs of this section to adapt the system for control from airdrop aircraft included the following:

Sensors:	Full System	Minimum System
	Altitude Airspeed Range Video	Depression Angle
Data Link:	**Full System**	**Minimum System**
	38 bits plus address	16 bits plus address

2.4 Cone-of-Silence Homing

2.4.1 General

Cone-of-Silence homing is similar to radial homing incorporating an expanded cone-of-silence. Ideally, the slope of the cone-of-silence is made identical to the glide slope of the gliding airdrop system. Only minor corrections are then required to guide it down the slope of the cone to produce an impact at the desired target. However, if the slope of the cone-of-silence exceeds the glide slope, and the airborne unit is programmed to turn away from the target whenever it penetrates the cone, satisfactory performance will result. This is fortunate, because it is impossible to exactly match the slopes of the cone-of-silence and the glide path, because the glide slope is continually changing during the flight depending upon the magnitude and relative direction of the wind being encountered.

Generating an antenna pattern with a true controllable slope of cone-of-silence is not practicable since the slope varies with the antenna patterns of the transmitting and receiving antennas, the transmitter power, and the receiver sensitivity. However, there is a technique that produces equivalent characteristics that is easily implemented. This technique utilizes the sense antenna tilt of a DF antenna comprised of loop and sense antennas. In this technique, the tilt angle of the sense antenna defines the effective slope of the cone-of-silence.

2.4.2 Airborne Subsystem

The complexity of a cone-of-silence homing system can vary. The basic system requires only a radial homing system in which proper sense antenna tilt has been deliberately introduced. Such a system is identified as cone-of-silence guidance minimum cost in figure 5. Adding an altimeter and data processor to the basic system permits improved performance. Finally, the antenna tilt can be used to measure depression angle as a part of a conical homing or full-state guidance system. It is assumed that a manual override capability is required by all guidance schemes.

Inspection of figure 5 shows that a cone-of-silence guidance system is comprised of the following:

(1) DF and Depression Angle Antenna System
(2) RF Receiver
(3) Synchronous Detector
(4) Altitude sensor
(5) Data Processor
(6) Manual Control Decoder
(7) Servo System
(8) Battery

Each of these is discussed in some detail in the following paragraphs.

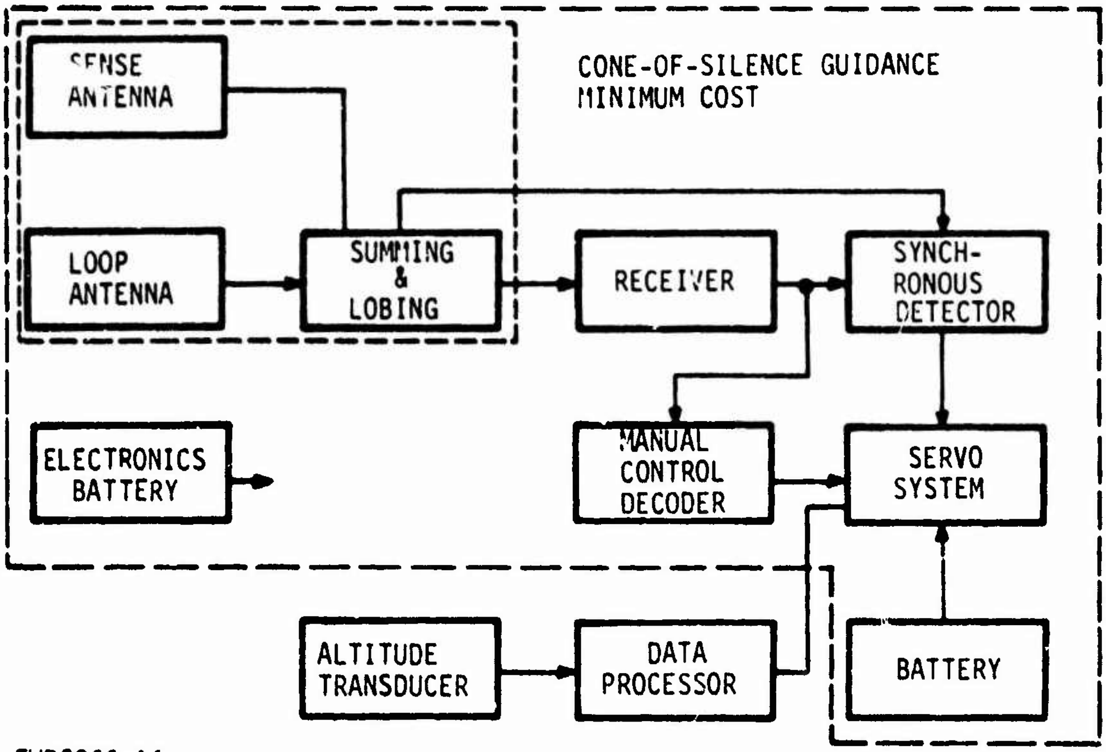

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Figure 5. Block Diagram Cone-of-Silence Homing With Manual Override: Airborne Subsystem

2.4.2.1 DF Antenna. - The DF antenna combines in phase the outputs from both a sense and a loop antenna, to generate a cordioidal-shaped antenna pattern.

To provide the equivalent of a controlled slope cone-of-silence, a phenomenon known as antenna tilt is utilized *, **. In an antenna system that generates a cordioidal antenna pattern by summing in-phase the outputs of a sense and a loop antenna, the effective angle of the cone-of-silence is identical to the tilt angle of the sense antenna. The directional indication reverses when this depression angle to the beacon occurs, because the output voltage from the sense antenna undergoes a phase reversal while the loop antenna output does not. During an actual beacon overpass, the output voltage of a sense antenna without tilt is of constant phase, while the loop antenna voltage output reverses at beacon overpass.

*H.H. Ward, 3rd, "Analysis of the Over-station Behavior of Aircraft Low Frequency ADF Systems", IRE Transactions - Aeronautical and Navigational Electronics, December 1955, p 51.

**J.T. Bolljahn and R.F. Reese, "Electrically Small Antennas and the Low Frequency Aircraft Antenna Problem", IRE Transactions - Antennas and Propagation, October 1953, p 51.

Sense antenna tilt is produced by mounting the sense antenna unsymmetrically on its ground plane. Figure 6 shows the required location of the sense antenna expressed as a fractional length of the ground plane required to produce a specified antenna tilt. Figure 7 shows the geometry involved. These figures show that for a ground plane of uniform cross section, the sense antenna tilt is linearly related to its displacement from the center of the ground plane, and that the direction of the tilt is reversed for top and bottom mounting. It should be noted that to anticipate the beacon passage as is required in cone-of-silence homing, a negative tilt angle is required.

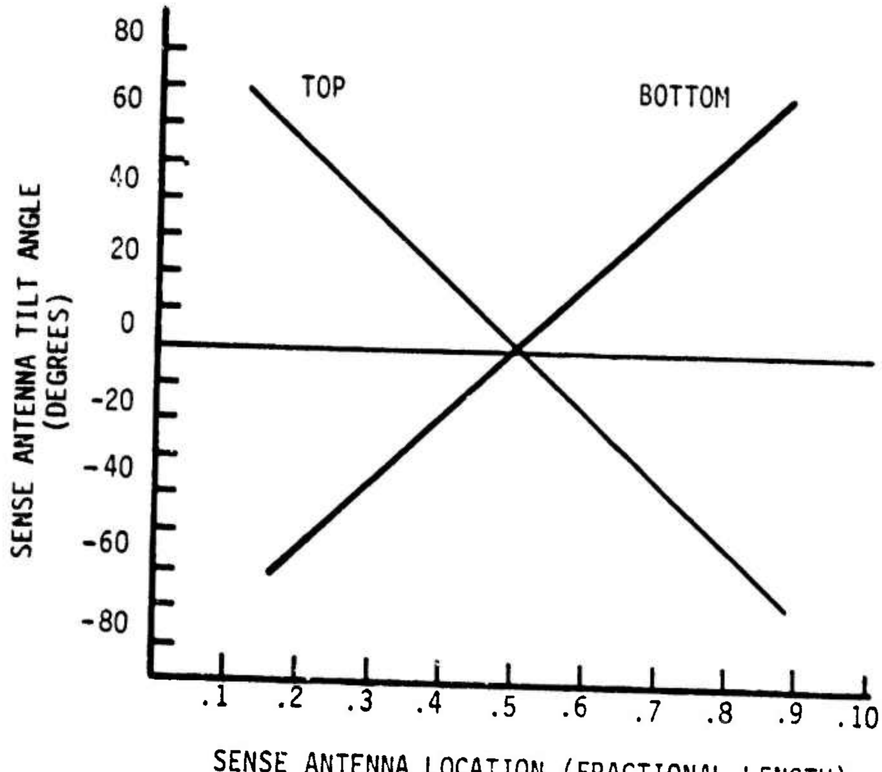

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Figure 6. Sense Antenna Location Versus Tilt Angle

To produce a tilt, the sense antenna must be mounted longitudinally assymetrically on its ground plane. This disymmetry causes the tilt angle to vary with the homing deviation angle of the guidance package. The variation is a function of both the shape of the ground plane and the homing deviation angle. Figure 7 illustrates this relationship. If a line joining the RF beacon, the sense antenna, and the rear corner of the ground plane remains within the angle bounded by θ_α, the sense antenna tilt angle remains constant. Beyond θ_α the tilt angle decreases linearly until it achieves a value of 0 degrees at θ_α = 90 degrees. This assumes a regular rectangular-shaped ground plane and center line mounting of the sense antenna.

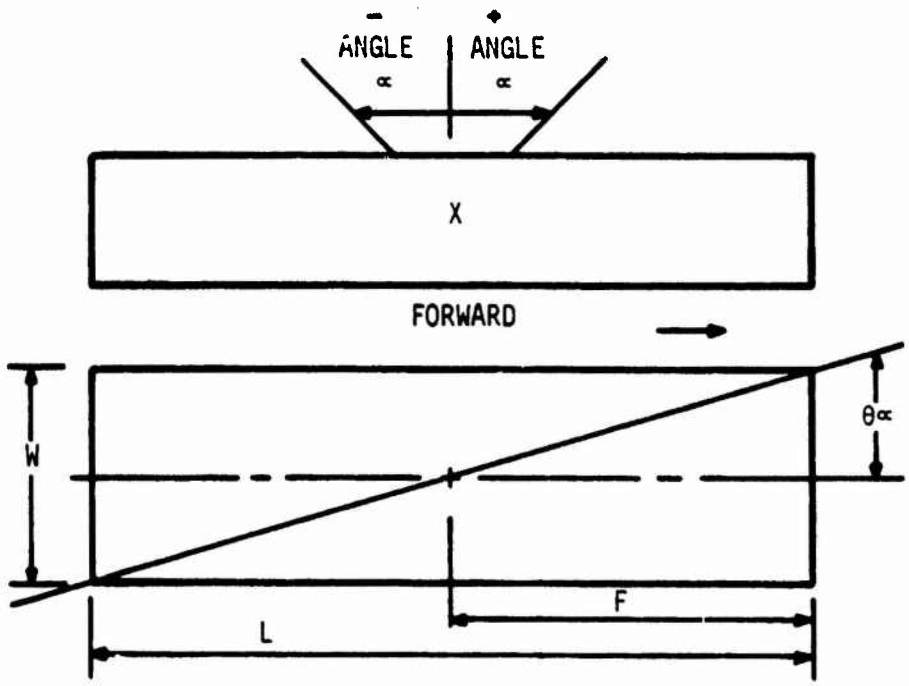

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Figure 7. Geometry Defining Tilt Angle Sense and Homing Deviation Angle For Constant Tilt Angle

The location of the sense antenna required to produce a specific sense antenna tilt angle can be computed from:

$F = (\alpha + 90)/K$ Bottom mounted antenna

$F = (\alpha - 90)/K$ Top mounted antenna

where:

F = Sense antenna location expressed as a fraction of the ground plane length.

α = Sense antenna tilt in degrees

K = Tilt Constant = 180 degrees

The value of $\theta\alpha$ can be evaluated from:

$$\theta\alpha = \frac{W}{2L(0.5 - \frac{\alpha}{180})}$$

where:

$\theta\alpha$ = Azimuth half angle within which α remains constant

W = Width of the ground plane

L = Length of the ground plane

These items are defined in figure 7.

Table 11 evaluates θ_α for values of α between 0 and -70 degrees when the antenna is mounted to a rectangular ground plane with L/W between 1 and 4. This table shows that θ_α decreases with increasing tilt angles, both positive and negative, and with increasing L/W ratios.

Table 11. α versus θ_α

α Degrees	θ_α For Ground Plane $\frac{L}{W}$ of			
	1	2	3	4
0	±180	±180	±180	±180
-10	±41.9	±24.2	±16.7	±12.7
-20	±39.3	±22.3	±15.3	±11.6
-30	±36.9	±20.6	±14.0	±10.6
-40	±34.7	±19.1	±13.0	± 9.8
-50	±32.7	±17.8	±12.1	± 9.1
-60	±31.0	±16.7	±11.3	± 8.5
-70	±29.4	±15.7	±10.6	± 8.0

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In coventional ADF systems, the phase reversal caused by a tilted sense antenna is undersirable. Ward* has shown that by increasing the phase shift between the loop and the sense antenna to greater than 90 degrees, this phase reversal can be made to occur only at altitudes above the flight altitude of the system. Cone-of-silence homing depends upon the tilted sense antenna caused phase reversal, and to ensure that it occurs at any flight altitude, the phase shift between the sense and loop output voltages may not exceed 90 degrees.

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*H.H. Ward, 3rd, "Analysis of the Over-Station Behavior of Aircraft Low Frequency ADF Systems", IRE Transactions - Aeronautical and Navigational Electronics, December 1955, p 51.

Physically, it is relatively easy to position the sense antenna with sufficient precision to establish the antenna tilt angle to within one degree (see figure 8). However, the accuracy to which the tilt angle can be resolved is less because of the small voltage output produced by the sense antenna when the depression angle is equal to the antenna tilt angle. During this condition the beacon is located in the null of the pattern of the sense antenna, causing the antenna output voltage to be small. This reduces the slope of the E_R-E_L characteristic, and produces a signal with small percentage lobing modulation. A relatively high signal-to-noise ratio is required to accurately process signals with small modulation precentages. Fortunately, at short ranges where high accuracy is required, strong signals will exist, and a reasonably good signal-to-noise ratio may be expected. It is estimated that the depression angle can be resolved to within ±2 degrees, and certainly to within ±5 degrees.

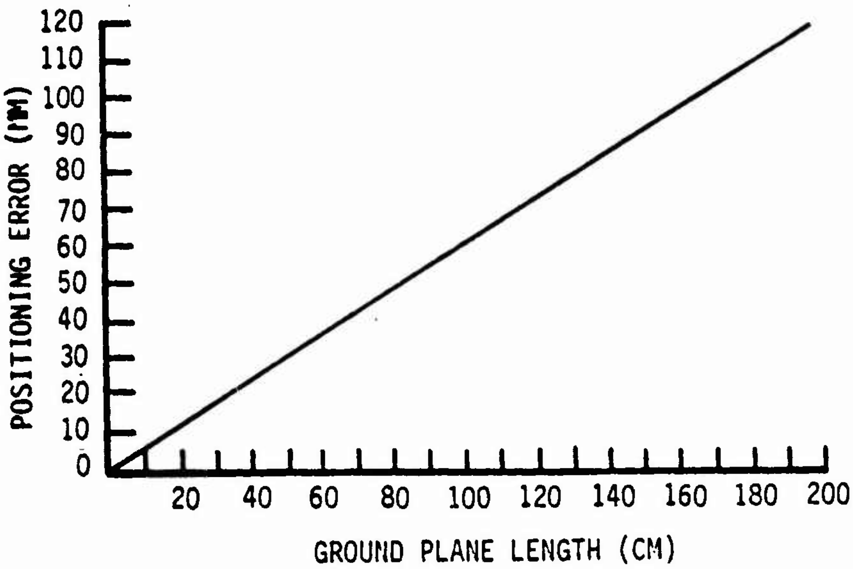

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Figure 8. Positioning Error of Sense Antenna For ±1 Degree Tilt Angle Error

There is nothing peculiar about the loop antenna requirements. For maximum voltage output is Q should be as high as possible. As in all loops that produce figure-of-eight radiation patterns, its size must be such that constant current flows throughout. This limits its area to approximately 0.001 λ^2. At lower frequencies, ferrite cores are useful, but at higher frequencies their advantage disappear. To prevent susceptibility to undesired voltages induced by the electric field in which it is immersed, the loop antenna must be shielded.

2.4.2.2 RF Receiver. - The receiver characteristics required for Cone-of-Silence Homing are identical to those required for Radial Homing with Enhanced Manual Control. However, its frequency will differ to be compatible with the loop-sense DF antenna.

2.4.2.3 Sensor Subsystem. - In its rudimentary configuration, the only sensor required is the DF antenna. This antenna system, when sense antenna tilt is introduced, functions to measure the homing deviation and the cone-of-silence angles. At the artificial beacon passage caused by the antenna tilt, the sense of the error signal is reversed, signalling the servo system to reverse the heading of the guidance package. Prior to the anticipated beacon passage, the DF system output provides normal left-right steering signals to maintain the airdrop package on a homing heading toward the beacon transmitter.

For improved performance, an altitude sensor may be added. Its function is to terminate the "turn-away" maneuver when the altitude is insufficient for the system to return to a homing heading prior to impact.

2.4.2.4 Synchronous Detector. - This is actually a phase detector that provides an output voltage whose magnitude and polarity are determined by the direction and magnitude of the angle of arrival of the rf signal relative to antenna boresight.

2.4.2.5 Control Decoder. - The function of the control decoder is to decode the manual control commands modulated onto the ground transmitter to provide a control signal to the servo system. It is identical to the control decoder described in subsection 2.2.2.3.

2.4.2.6 Servo Actuator. - These modules are identical to those described in subsection 2.2.2.5. They will differ for each payload and canopy requirement, but will be identical for a given payload and unaffected by the guidance technique selected.

2.4.2.7 Primary Power. - The optimal primary power for the airborne system is a lead acid battery system. Depending upon the servo motor requirements established by the payload, the voltage and current capabilities needed will vary. The basic battery can probably be the same for all systems. Different combinations that provide specific voltage and current capabilities will be assembled from them. These are addressed in greater detail in subsection 2.2.2.5.

2.4.2.8 Sensor Subsystem For Augmented Cone-of-Silence Homing. - The sensor subsystem consists of the homing deviation angle sensor, the depression angle sensor, and the altimeter. The homing deviation and depression angle are measured by the antenna system described in subsection 2.4.2.1. The altitude sensor is a pressure transducer whose characteristics are addressed in subsection 2.5.1 in conjunction with the CHMS Guidance System.

2.4.2.9 Data Processor. - The data processor for Cone-of-Silence homing can be relatively simple. In its simplest form, it merely inhibits the turn-away maneuver when the altitude of the airdrop unit is insufficient for it to execute a turn-away maneuver and recover to an up-wind heading. A more complex processor will compute the optimum heading and duration of the turn-away maneuver to ensure minimum miss distance and an up-wind impact.

2.4.3 Ground Subsystem

The ground subsystem required for cone-of-silence homing differs from that used for radial homing only in frequency and RF output power capability.

2.4.3.1 RF Source. - The RF Source will consist of a crystal-controlled or synthesized frequency source followed by a power amplifier capable of being modulated by the manual control command encoder. It may be desirable to provide identification modulation of the signal transmitted from the ground beacon for the convenience of the airdrop aircraft personnel making the delivery. Selectable morse code letters or tones can be easily generated and modulated on the carrier for identification. The pulse modulation may of itself be sufficient identification. Omnidirectivity in azimuth and broad vertical patterns is desired from the transmitting antenna which is a part of the rf source. HF and VHF antennas typically are monopole types that use the case of the transmitter as a part of their ground plane, which quite often results in undesirable antenna patterns. For cone-of-silence homing, where the most probable operating frequency lies in the frequency range between MF and VHF, a monopole working against a ground plane is the type most likely to be selected. Both wire and metalized cloth counterposes have been found highly effective in improving the readiation efficiency and radiation patterns of antennas in this frequency range.

2.4.3.2 Command Encoder. - The command encoder is identical to that decribed in subsection 2.2.3.2.

2.4.3.3 Primary Power. - Primary Power source will be as described in subsection 2.1.3.

2.4.4 Cost Summary

An estimate of the Cone-of-Silence Homing Cost Summary has been compiled and is found in table 12.

Table 12. Cone-of-Silence Homing System Cost Summary

Item	Cost Payload 500	Capacity 2000	Pounds 15000
Airborne Subsystem			
Depression Angle and Homing Deviation Angle Antenna System	100	100	100
Medium Frequency Receiver	150	150	150
Synchronous Detector	25	25	25
Control Decoder	100	100	100
Altitude Transducer	700	700	700
Data Processor	500	500	500
Subtotal	$1575	$1575	$1575
Servo System and Batteries	544	1200	2197
Total	$2119	$2775	$3772
Ground Subsystem			
Beacon Transmitter with Antenna, Control Encoder and Batteries	$1000	$1000	$1000

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2.5 Full State Guidance CHMS

2.5.1 General

In this section, descriptions of two full-state guidance systems are presented. One represents a highly precise and costly approach, the other a less precise, but considerably lower cost approach. The first system uses interrogator-transponder DME techniques to measure the slant range to the target. The second utilizes depression angle measurement via an on-board antenna, combined with the data from an on-board altimeter to determine the slant range to the ground beacon target. Additional sensors and the steering servo systems required by the two approaches are identical.

In addition to addressing and comparing alternate approaches, the sensors required for each selected approach are addressed in some detail.

2.5.1.1 Sensors. - Sensors are required to provide information to the data processing portions of the system concerning the instantaneous state of the airdrop subsystem, so that proper steering commands can be generated to guide it along the desired trajectory. The following parameters must be determined:

(1) Vector position of the airdrop system relative to the target site

(2) Inertial heading of the airdrop system

(3) Altitude above the drop zone

(4) Airspeed, both horizontal and vertical of the airdrop system

The following parameters may be measured either directly, or derived from the parameters measured above:

(1) Range and range rate
(2) Rate of change of heading
(3) Rate of change of Homing Deviation Angle

In the following paragraphs potentially suitable sensors are considered, and restrictions regarding the suitability of these instruments are weighted. Where significant, summarized characteristics of representative instruments are presented. In general, more complete data and decriptions are provided by the data sheets included as Appendices to this document.

2.5.1.1.1 Position. - There are numerous methods which can determine the instantaneous position of the airdrop system. However, only a few of these are suitable for this application. Many are rejected because their

location accuracy is inadequate, others because their position data is not continuously available and still others because their cost, size, or time to set up are excessive. Table 13 lists some potential candidate position measurement systems and a summary of their characteristics.

Of the candidate systems listed in table 13, the Navstar Global Position System (GPS) appears fully useful, but its usefulness must await deployment of the full complement of 24 satellites in 1984 to be really practicable. The airborne navigation set has not yet been built, but the "Z" system is specified as a light, low cost ($15K) set that will be compatible. A navigation fix requires 5 to 6 seconds, and navigation data is continuously available. It is designed to operate through extremely high level jamming signals. It is a passive system and detectability is low because no beacon is required at the Drop Zone. The Motorola Mini-Ranger III system is suitable and is immediately available.

The following three are the usual methods of position measurement:

(1) Range-Range
(2) Range-Angle
(3) Angle-Angle

Range is usually measured by some form of transit time system, such as radar, or an interrogator-transponder. Angle can be measured by phase or amplitude comparison type antenna systems. In a range-range system, the position fix relies on tri-lateration. A range-range system requires at least two stations whose locations are accurately known relative to each other. A range-angle measurement requires only one station but it must possess the capability for measurement of range and angle. Radar is an example of such a system. An angle-angle measurement also requires two stations at known locations. Only angle measurement capability is required from each of these stations.

The search for suitable available position measurement systems revealed that an interrogator-transponder system is nearly optimal for the range measurement. Systems providing range measurement accuracies to a few centimeters are available, but these systems are probably too expensive ($200K/pair) to be considered for this application. Motorola's Mini-Ranger III system provides a range accuracy of ±3 meters and was judged to be the most cost effective equipment encountered.

Angle measurements can most effectively be made by an ADF. Collins Radio's DF-301E appears to meet most angle measurement requirements of the system, although it may require calibration to provide the needed angular accuracy. Its bearing accuracy is specified as 2.5 degrees RMS under standard conditions.

One other method considered for measuring range, combines depression angle and altitude measurements, from which ground and slant ranges can be computed. The depression angle is measured using the antenna tilt

Table 13. Position Fixing Systems

System	Estimated maximum range	Estimated accuracy	Frequency range	Comments
DECCA	200-300 NM	±0.25-1.0 NM	90-130 kHz	Operational with localized coverage, limited to about 240 Mi range at night because of sky wave interference.
LORAN-A	700-900 NM	±0.5-2.0 NM	1.75-2 MHz	Operational with localized coverage, limited by sky wave interference. Relatively inexpensive.
LORAN-C	1200-1500 NM	±0.2-0.5 NM	90-110 kHz	Operational with localized coverage, limited by sky wave interference. Relatively accurate except with sky wave.
OMEGA	5000 NM	±1.0-2.0 NM	10-14 kHz	Planned to give worldwide coverage, using eight ground stations and three operating frequencies. Presently in developmental stage with four ground stations and three operating frequencies yielding lane ambiguity every 72 NM.
SATELLITE TRANSIT NNSS	Worldwide	0.10 NM	150-400 MHz	Operational with worldwide, all-weather, 24-hour coverage. Transit satellites provide position fix approximately every 90 minutes. Presently six operational satellites.
SATELLITE GPS 2D	Worldwide 1981	POS ±300 M VEL ±2 KTS	L1-1.57 GHz L2-1.22 GHz	Operational worldwide with 24-hour all-weather coverage. Satellites will provide continuous NAV information. The 2-D phase will provide 9-12 satellites in 3 orbital planes. 3-D will have 24 satellites in the same planes.
3D	Worldwide 1984	POS ±8 M VEL ±0.1 KTS ALT ±10 M	L1-1.57 GHz L2-1.22 GHz	
Teledyne Hastings Raydist DRS-H	500 km	±2 M	1600-4500 kHz	Range-range requires 2 stations 4 users maximum. Set up time: 1/2 day, 3 men.
Cubic Corp Shiran	800 km	±3.2 M	3.312 GHz 3.087 GHz	Interrogator-Transponder. Requires 4 ground stations.
Humphries Inertial Reference System CF32-0201-1		Yaw 0.1^{o}/nm		3 axis inertial reference system.
Motorola Mini-Ranger III	19 km with omni 6 dB antenna	Range accuracy ±3 M	5.4 GHz 5.6 GHz	Range-range requires master and 2 reference stations. Can also be used in tracking mode with up to 16 simultaneous users.

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of the sense antenna element of a loop-sense DF antenna described in subsection 2.4.2.1. This measurement is less precise than other proposed techniques, but its accuracy may be sufficient to be useful, since that accuracy improves as the range decreases.

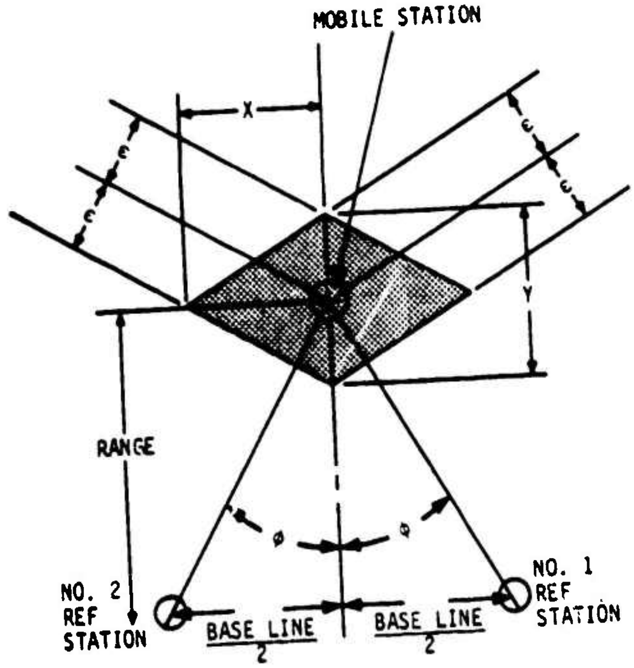
The fix accuracy provided by a range-range measurement is a function not only of the range accuracy of the individual stations comprising the system, but also the accuracy of their siting and their geometry; primarily the angle of the intersection of their range arcs. The fix accuracy of a range-angle measurement is dependent upon the accuracy of both the range and the angle measurements. Its accuracy is also proportional to range if its range and angular accuracies remain constant. Figure 9 shows the geometry, a method for computing the position uncertainty of a range-range system, and the angular accuracy required from a range-angle system that provides the same uncertainty. In table 14, the rms position error is computed for ranges between 0.09 and 18.5 km. For each range and base line, the angular accuracy required to produce the same rms error is shown. These calculations are based upon the stated accuracy of the Motorola Mini-Ranger II system of ±3 meters. Figure 10 illustrates the angular dependence of the accuracy of a range-range system upon the range arc intersection angle. This, in turn, is a function of the range to the target and the base line length. Figure 10 shows that the accuracy changes only slightly for intersection half angles between 15 and 70 degrees, but degrades rapidly beyond these limits. These calculations were based upon a range uncertainty of three meters.

The range accuracy that can be achieved using measurement of the depression angle and the altitude of the airdrop package, is a function of accuracy of the measurements of the angle and the altitude. The error in range that results at depression angles between 30 and 60 degrees with measurement accuracies of 1, 2, and 5 degrees (at altitudes between 100 and 1000 meters) is shown in table 15. The uncertainty in the altitude measurement must be added to the tabulated errors. For the Rosemount Altitude Transducer, the altitude error is quite small (±3 meters) for altitudes below 1 km, and in the worst case would increase the range error by only three precent.

Having approximated the accuracy that can be achieved by range-range and by range-angle positioning systems, their relative costs must be assessed prior to recommending a specific configuration. The following five position determining configurations were analyzed:

Configuration	
I.	Mini-Ranger III DME with Airborne DF
II.	Mini-Ranger III DME with Ground ADF
III.	Mini-Ranger III Tracking Mode
IV.	Mini-Ranger III Standard System
V.	Depression Angle with Airborne ADF

Each of these configurations is addressed in subsequent paragraphs.



SYMBOLS

R = Range to Mobile Unit
ε = Range Measurement Error of P,P, or P,θ System
θ = Bearing Measurement Error of P,θ System
2θ = Intersection Angle of Range Measurements

$$\phi = \text{Arc Tan}\left(\frac{\text{Base Line}}{2 \times \text{Range}}\right)$$

drms = Radius of Circle of Area Equal to Measurement Uncertainty

$$X = \varepsilon/\text{SIN}\phi \qquad Y = 2\varepsilon/\text{COS}\phi$$

$$\text{Area of Measurement Uncertainty} = \frac{XY}{2} = \frac{2\varepsilon^2}{\text{SIN}\phi\text{COS}\phi}$$

$$\text{drms} = \varepsilon\left(\frac{2}{\pi\text{SIN}\phi\text{COS}\phi}\right)^{1/2}$$

$$\theta = \frac{\text{drms}}{R} \times \frac{180}{\pi} \text{ degrees}$$

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Figure 9. Measurement Uncertainty Calculation Geometry For Range-Range Position Fixes

Table 14. Position Accuracy
Versus Range for ρ-ρ and ρθ Systems

Base line	1.85 KM			0.46 KM			0.185 KM			0.100 KM		
Range KM	ϕ^o	drms M	θ^o	ϕ^o	drms M	θ^o	ϕ^o	drms M	θ^o	ϕ^o	drms M	θ^o
0.09	84.2	7.54	4.8	68.2	4.076	2.596	45.0	3.385	2.15	4.55	8.512	5.419
0.18	78.7	5.42	1.726	51.3	3.427	1.095	26.6	3.783	1.204	4.25	8.805	2.802
0.46	63.4	3.78	0.47	26.6	3.783	0.472	11.3	5.461	0.680	3.43	9.795	1.220
0.93	45.0	3.38	0.208	14.0	4.941	0.304	5.7	7.614	0.470	2.43	11.630	0.716
1.39	33.7	3.52	0.146	9.5	5.933	0.244	3.8	9.308	0.384	1.82	13.435	0.554
1.85	26.6	3.78	0.118	7.12	6.825	0.212	2.86	10.723	0.332	1.44	15.102	0.468
3.70	14.0	4.94	0.076	3.58	9.588	0.148	1.43	15.155	0.304	0.76	20.785	0.322
5.55	9.5	5.933	0.062	2.38	11.751	0.122	0.96	18.494	0.190	0.51	25.372	0.262
7.40	7.1	6.835	0.052	1.79	13.547	0.104	0.72	21.354	0.166	0.38	29.393	0.228
9.25	5.7	7.614	0.048	1.43	15.155	0.094	0.57	23.999	0.148	0.31	32.542	0.202
11.10	4.8	8.289	0.044	1.19	16.612	0.086	0.48	26.152	0.134	0.26	35.534	0.184
12.95	4.1	8.963	0.040	1.02	22.487	0.100	0.41	28.297	0.126	0.22	38.629	0.170
14.80	3.6	9.562	0.038	0.90	19.100	0.074	0.36	30.198	0.116	0.19	41.567	0.160
16.65	3.2	10.139	0.034	0.80	20.258	0.070	0.32	32.030	0.110	0.17	43.944	0.151
18.50	2.9	10.649	0.032	0.72	21.354	0.066	0.28	34.241	0.106	0.16	45.296	0.140

NOTE: Range Accuracy = ±3 Meters
(Both Channels)

2ϕ = Intersection Angle or Range Vectors of ρ,ρ System

θ = Bearing Accuracy of θ required to produce same position accuracy with ρ,θ System as in ρ,ρ System with same range accuracy.

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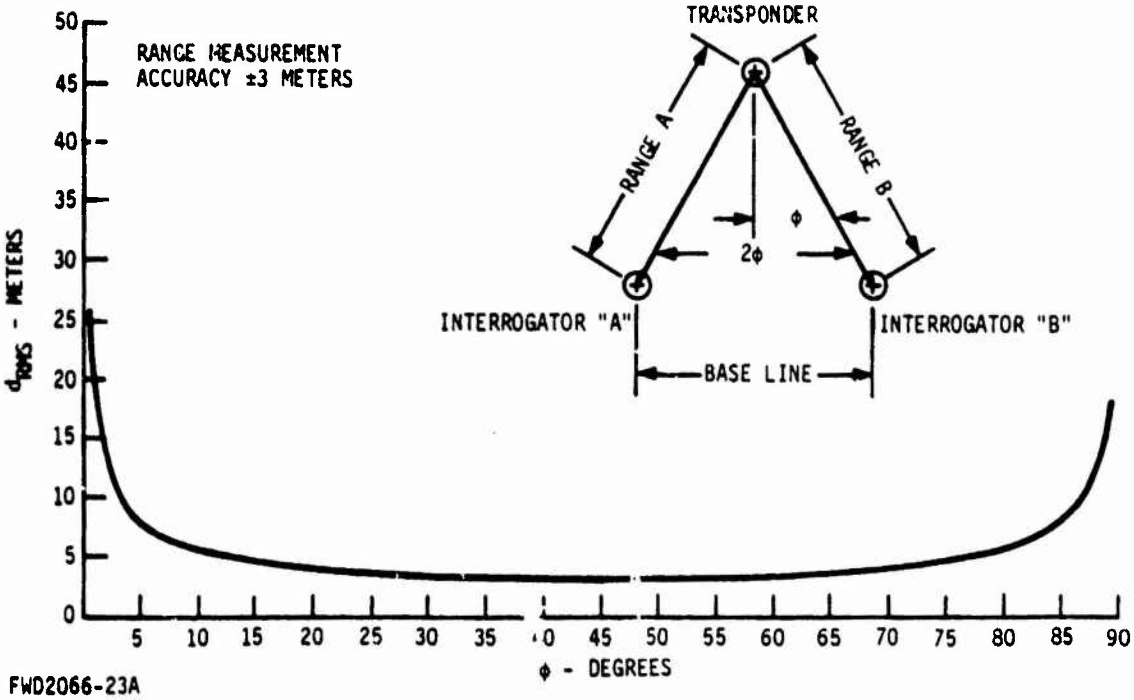

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Figure 10. d_{RMS} Versus Ø For Range-Range Positioning System

Table 15. Range Error From Depression Angle Measurement

Depression angle degrees θ	Range error in meters								
	30^0			45^0			60^0		
Tolerance degrees Δθ / Altitude meters	±1	±2	±5	±1	±2	±5	±1	±2	±5
100	± 6.3	± 13.0	± 36.6	± 2.5	± 5.2	± 14.2	± 1.2	± 2.5	± 6.6
200	±12.5	± 26.0	± 73.2	± 5.0	±10.4	± 28.3	± 2.4	± 4.9	±13.2
500	±31.3	± 65.0	±183.0	±12.5	±26.0	± 70.8	± 6.0	±12.2	±33.0
1000	±62.6	±130.0	± 36.6	±25.0	±52.0	±141.5	±11.9	±24.5	±66.1

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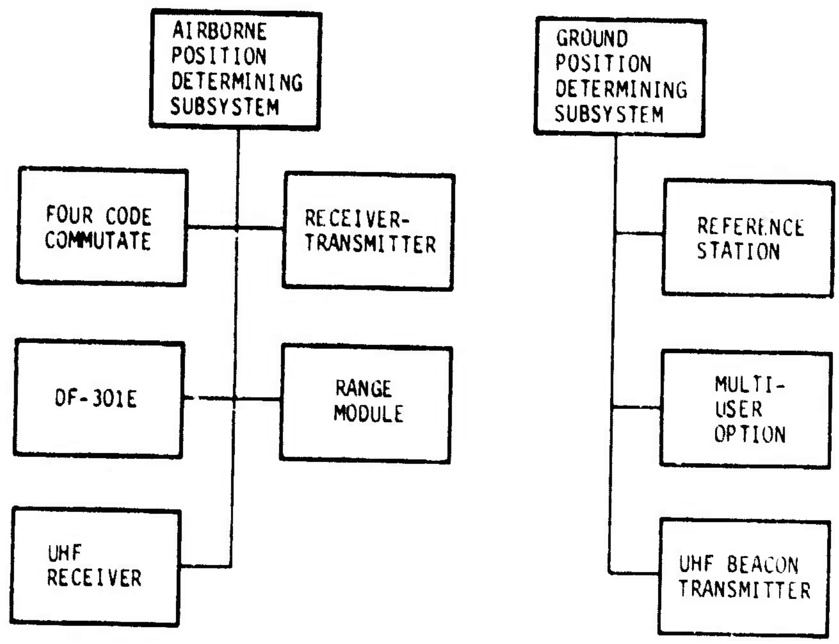
2.5.1.1.1.1 Mini-Ranger III DME with Airborne DF. - The Mini-Ranger III DME consists of only a single interrogator and transponder that provides the airborne-to-ground station range required for a range-angle position fix. An airborne ADF provides the necessary angular measurement. Family trees defining the components of the airborne and ground stations are included in figure 11.



ITEM DESCRIPTION	MANUFACTURER AND MODEL NO.	COST
Airborne Subsystem		
Receiver-Transmitter	Motorola Mini-Ranger III	$ 5,572.00
Range Module	Motorola Mini-Ranger III	724.00
Four Code Commutate	Motorola Mini-Ranger III	861.00
ADF	Collins Radio DF-301E	2,756.00
UHF Receiver	Magnavox	200.00
	Total	$10,113.00
Ground Subsystem		
Reference Station	Motorola Mini-Ranger III	$ 4,370.00
Multi-User Option	Motorola Mini-Ranger III	794.00
UHF Beacon Transmitter	Magnavox	500.00
	Total	$ 5,664.00

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Figure 11. Family Trees and Cost of Configuration I Position Determining Subsystem: Mini-Ranger III DME-Airborne ADF

For purposes of this analysis, it has been assumed that four air-drop subsystems will be simultaneously used with a single ground station. This assumption affects the Mini-Ranger III equipment complement required.

The range measurement requires the following Mini-Ranger III modules in the airborne unit: Reference Station, Range Module, and Four Code Commutate Module. It is assumed that a similar microprocessor will be used to perform the calculations to transform the sensor data into a position fix for all configurations, and is not included in any of these configurations.

The angle measurement is made by an on-board ADF (Collins DF-301E) which requires an UHF receiver; however this receiver is also required to receive the manual control commands.

As tabulated in figure 11, the cost of the airborne unit is $10,113.00 each.

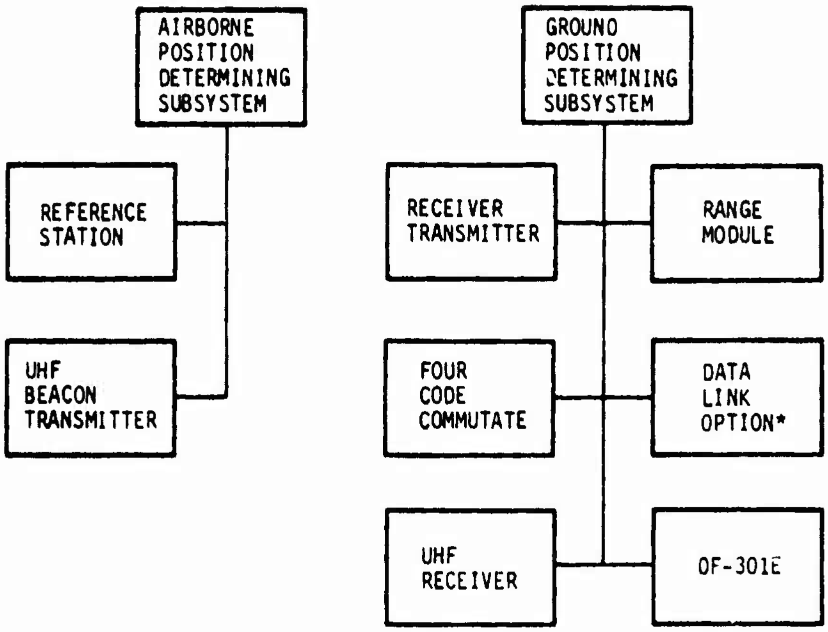
The ground station consists of two Mini-Ranger III components: a Reference Station and a Multi-user Module. It also includes a UHF Beacon Transmitter that performs the dual functions of providing a homing source for Heading Deviation Angle Measurements, and an up-link for transmitting manual steering commands to the airborne unit. The cost of the ground station portion of the positioning system is estimated at $5,664.00.

2.5.1.1.1.2 Mini-Ranger III DME with Ground ADF. - Family trees of this configuration are shown in figure 12. The airborne subsystem consists of a Mini-Ranger III Reference Station and an UHF Beacon Transmitter.

The Ground subsystem consists of Mini-Ranger III components as follows: Receiver-Transmitter, Range Module, Four Code Commutate, and Data Link Option. As noted in figure 12, one Data Link Option is required for each mobile unit that interfaces with the ground station. To accurately reflect this cost in a system consisting of multiple Airborne Stations per Ground Station, the cost of the Data Link module is listed as a part of the Airborne Subsystem. The cost of the airborne subsystem is $11,870.00 and that of the ground subsystem $10,113.00.

In this mode, the range to the mobile is measured at the ground station and data-linked to the mobile station on the signal transmitted by the Receiver-Transmitter.

Angle measurement is made at the ground station by a Collins DF-310E angle-tracking the UHF Beacon Transmitter aboard the Airborne Subsystem. When only a single airborne subsystem is used, this approach performs well, but when multiple airborne subsystems must be simultaneously guided, complications arise. Some method is required to assure that the bearing and range measurements are from the same airborne subsystem. One possible method to accomplish this is using the stretched keying pulse from the transponder of the airborne subsystem to also key the UHF Beacon Transmitter. Because the antenna pattern of the DF-301E



ITEM DESCRIPTION	MANUFACTURER AND MODEL NO.	COST
Airborne Subsystem		
Reference Station	Motorola Mini-Ranger III	$ 4,370.00
*Data Link Option	Motorola Mini-Ranger III	7,000.00
UHF Beacon Transmitter	Magnavox	500.00
	Total	$11,870.00
Ground Subsystem		
Receiver Transmitter	Motorola Mini-Ranger III	$ 5,572.00
Range Module	Motorola Mini-Ranger III	724.00
Four Code Commutate	Motorola Mini-Ranger III	861.00
ADF	Collins Radio OF301E	2,756.00
UHF Receiver	Magnavox	200.00
	Total	$10,113.00

*Data Link Option is located in the Ground Station, but since one is required for each airborne subsystem in use simultaneously, option cost is shown in Airborne Subsystem to allow accurate computation of system cost.

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Figure 12. Family Trees and Cost of Configuration II Position Determining Subsystem: Airborne Mini-Ranger III DME-Ground ADF and Data Link

is electronically scanned, its angular response is many times faster than an electromechanically rotated antenna. The response time of the phase detector circuits, instead of the antenna scan rate, will determine the minimum acquisition dwell times that must be allowed for each angular measurements. If two or more beacon transmitters are energized simultaneously, the bearing indication will be in error. This problem cannot be soved by providing unique modulation of each beacon transmitter and selective filtering at the ADF receivers.

In addition to the relatively high cost of this configuration, the difficulty encountered in accurately measuring bearing angles in a multi-user environment detracts from its desirability.

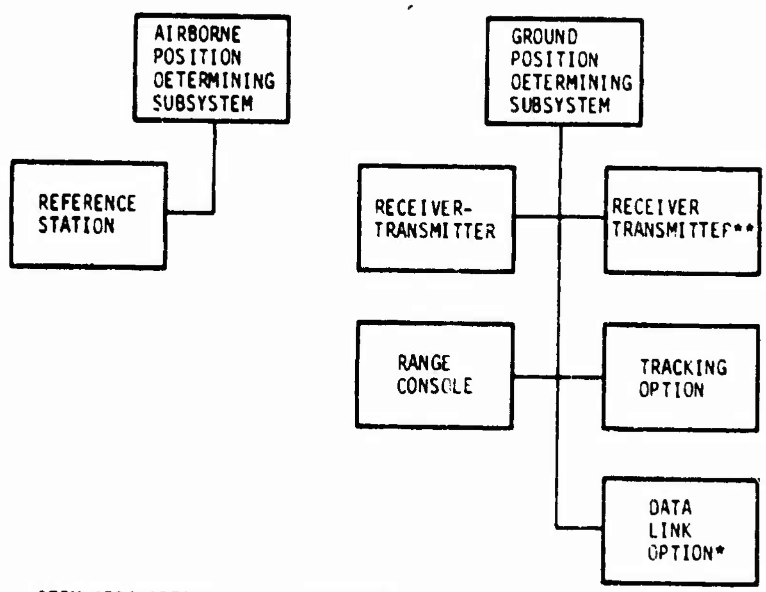
2.5.1.1.1.3 Mini-Ranger III Tracking Mode. - This mode uses tri-lateration to estabilsh the position of up to 16 mobile stations. A control station and a fixed station are placed with a known separation at known locations which maintain line-of-sight contact between all stations. One of the receiver-transmitter units at the control station sends an interrogation. When the mobile unit receives the interrogation, it transmits a reply. The control station receives this reply and the reuslting range R1, is computed.

The reply is also received by the fixed station which retransmits it to the control station. The reply is received on the other receiver-transmitter and the loop range R2, is determined. R1 represents the distance in meters from the control station to the mobile. R2 represents one half the distance around the loop. The distance from the fixed to the mobile station is computed from: 2R2 - (Base Line Length +R1). The intersection of these two range arcs, one centered about the control station and the other about the fixed station, gives the location of the mobile.

This approach is accurate (see table 13) and makes maximum use of off-the-shelf position determining equipment. The equipment complement of the Airborne and Ground subsystems is shown in figure 13. All components are those of the Motorola Mini-Ranger III.

The cost of the Airborne Subsystem is shown in figure 13 as 11,370.00, and that of the Ground Subsystem as $29,719.00. It is a relatimely expensive, although accurate, method of position determination. It requires precise knowledge of the baseline length, and the position of the fixed station relative to the control station.

2.5.1.1.1.4 Standard Mini-Ranger III System. - This configuration uses the standard Mini-Ranger III system. The Airborne Subsystem contains a Mini-Ranger III Receiver Transmitter and Range Console. The Ground Station consists of two Mini-Ranger Reference Stations. The reference stations are sited to provide line-of-sight view of the mobile station at known locations with a known separation. The range to each reference station is measured by the airborne equipment, and these range measurements are translated through tri-lateration into a position fix. The family trees of this configuration are shown in figure 14.



ITEM DESCRIPTION	MANUFACTURER AND MODEL NO.	COST
Airborne Subsystem		
Reference Station	Motorola Mini-Ranger III	$ 4,370.00
Data Link Option*	Motorola Mini-Ranger III	7,000.00
	Total	$11,370.00
Ground Subsystem		
Receiver-Transmitter	Motorola Mini-Ranger III	$ 5,572.00
Tracking Option	Motorola Mini-Ranger III	8,533.00
Range Console	Motorola Mini-Ranger III	11,244.00
Reference Station	Motorola Mini-Ranger III	4,370.00
	Total	$29,719.00

*Data Link Option is located in the Ground Subsystem but because one each is required for each Airborne subsystem, its cost is shown as a part of the Airborne to allow comparison of system costs.

**Cost of second Receiver Transmitter is included in the tracking option cost.

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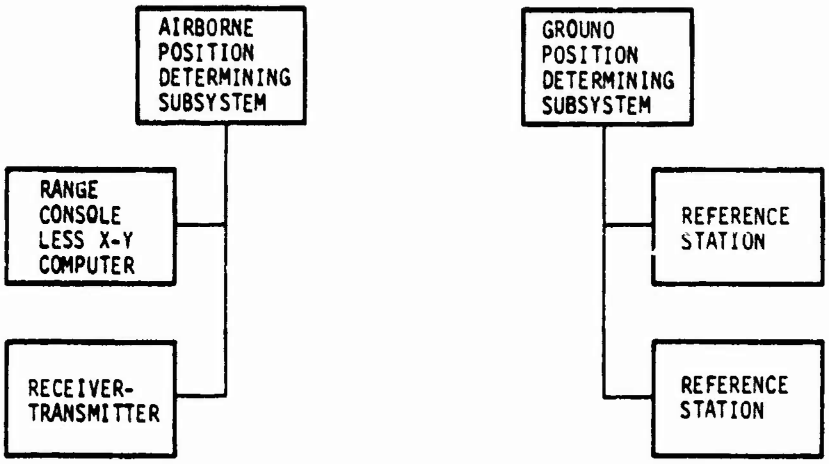
Figure 13. Family Trees and Cost of Configuration III Position Determining Subsystem: Mini-Ranger III Tracking Mode



ITEM DESCRIPTION	MANUFACTURER AND MODEL NO.	COST
Airborne Subsystem		
Receiver-Transmitter	Motorola Mini-Ranger III	$ 5,572.00
Range Console Less X-Y Computer	Motorola Mini-Ranger III	10,244.00
	Total	$15,816.00
Ground Subsystem		
Reference Station	Motorola Mini-Ranger III	$ 4,370.00
Reference Station	Motorola Mini-Ranger III	4,370.00
	Total	$ 8,740.00

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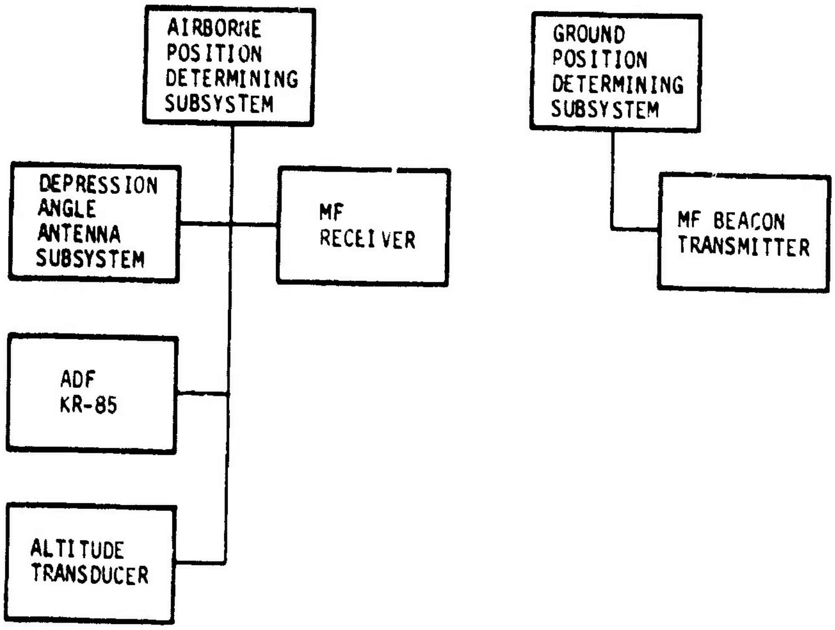
Figure 14. Family Trees and Cost of Configuration IV Position Determining Subsystem: Standard Mini-Ranger III

This configuration also uses off-the-shelf Mini-Ranger III equipment entirely. Its accuracy is also high, but it, too, requires accurate siting of the ground stations. Figure 14 also shows that it is a retively costly approach. The airborne subsystem cost is $15,816.00 and the ground subsystem $8,740.00.

2.5.1.1.1.5 Depression Angle with Airborne DF. - This approach represents a minimum cost, low accuracy method of position fixing. The family trees of the Airborne and Ground subsystems are shown in figure 15.



ITEM DESCRIPTION	MANUFACTURER AND MODEL NO.	COST
Airborne Subsystem		
Depression Angle Antenna	Magnavox	$ 400.00
MF Receiver	Magnavox	150.00
ADF	King Radio Model KR-85	1695.00
	Total	$2245.00
Ground Subsystem		
MF Beacon Transmitter	Magnavox	$ 500.00

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Figure 15. Family Trees and Cost of Configuration V Position Determining Subsystem: Airborne Depression Angle and ADF

In this configuration, the range is determined from depression angle and altitude measurements. The depression angle is measured using sense antenna tilt as described in subsection 2.4.2.1. A servo varies the position of the sense antenna on its ground plane until the sense antenna tilt angle equals the depression angle to the beacon transmitter. Only negative tilt angles are useful, consequently, the sense antenna must travel the length of the ground plane to provide negative tilt angles when the heading is either toward or away from the ground beacon transmitter.

The homing deviation angle is measured by a King Radio ADF, Model KR-85. In this system the loop and sense antennas are combined into a single package. Also, the receiver and bearing determining circuits are combined into a single unit. The advantage of using this ADF instead of the Collins unit is that a single beacon can be used for Homing Deviation Angle and Depression Angle measurements. Because the upper frequency limit of the KR-85 is 1750 kHz, the upper frequency of the system is determined by its tuning range unless it is modified.

The ground station is relatively simple consisting only of an HF Beacon Transmitter that is used by both the depression angle and the homing deviation angle sensors.

The cost to implement this system is modest: $2245.00 per Airborne, $500.00 per ground subsystem. Its accuracy is significantly poorer than other techniques as shown in figure 15.

2.5.1.1.1.6 Cost comparison of Position Fixing Methods. - The estimate cost of basic airborne and ground subsystems of each of the positioning methods is tabulated in table 16. Also, the more meaningful system costs are presented assuming that a system consists of four airborne subsystems per ground subsystem. The ranking of configurations in ascending order of their system costs is as follows:

(1)	Configuration	V	Depression Angle with Airborne DF
(2)	Configuration	I	Mini-Ranger III DME with Airborne DF
(3)	Configuration	II	Mini-Ranger III DME with Ground DF
(4)	Configuration	III	Mini-Ranger III Standard
(5)	Configuration	IV	Mini-Ranger III Standard

Other assumptions concerning the number of airborne subsystems per ground subsystem will produce a different ranking. For example, the Mini-Ranger III Tracking configuration becomes more econmical than the standard DF Mini-Ranger III Configuration when the number of airborne subsystems per ground subsystems is increased to five.

2.5.1.1.2 Inertial Heading. - Determining the heading of the airdrop system during flight is essential to several of the proposed guidance schemes. Either a gyroscopic or a magnetic heading reference may be used. Neither of these instruments is ideal for this application, but it appears that either, or a combination of both, can meet the system requirements.

Table 16. Comparison of Position Determining Subsystem Cost

No.	Configuration description	Estimated cost: Airborne	Estimated cost: Ground	System cost 4 airborne + 1 ground
I	DME/Airborne DF	$10,113.00	$ 5,664.00	$46,116.00
II	DME/Ground ADF	$11,870.00	$10,113.00	$57,593.00
III	Mini-Ranger III Tracking Mode	$11,370.00	$29,719.00	$75,199.00
IV	Standard Mini-Ranger III	$15,816.00	$ 8,740.00	$72,004.00
V	Depression Angle/ Airborne DF	$ 2,245.00	$ 600.00	$ 9,580.00

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The limitations of both instruments result from the attitudes that the airdrop system can assume either during air deployment or during its normal flight. The most violent departure from normal attitude occurs during the air deployment phase where its attitude may be displaced up to 90 degrees about its pitch, roll, and yaw axes, and it may also experience deceleration forces of up to 15 g/s. During normal flight, the pitch and bank angles can be controlled by limiting the system to small or moderate rates of turn.

2.5.1.1.2.1 Gyroscopic. - Two types of gyroscopes in common usage are contenders for this application: heading and rate gyroscopes. A heading gyroscope establishes an inertial reference in space and outputs a voltage proportional to the magnitude of the angular departure from this heading reference. A rate gyroscope recognizes only the rate of change of heading. Rate information can be obtained from a directional type by noting the incremental angular change during a given interval. A rate gyro's output can be integrated to determine its angular departure from a reference heading. A heading type can tolerate only limited departure from normal attitudes.

When an uncaged heading gyro is subjected to pitch or roll angles exceeding, typically, 50 to 80 degrees, its gimbal system strikes a mechanical stop. This does one of two things: causes the gyro to tumble which destroys its inertial reference, or damages its bearings which degrades its accuracy. To avoid the occurence, the gyro can be caged ---

its gimbal system mechanically immobilized --- until the deployment transient has passed and then uncaged. The uncaged gyro lacks a reference to North or to any other pre-determined direction. However, by causing the airdrop system to assume and maintain a homing heading prior to and during the uncaging of the gyro, an initial inertial reference can be established that can be used in subsequent calculations. Directional gyros that can be remotely uncaged are readily available from several manufacturers.

Rate gyroscopes have no stops and cannot tumble. Consequently, deployment is not a severe trauma for them. However, they provide no heading reference, only an indication of the rate of change of heading. By continuously integrating the output from a rate gyro after the homing package has stabilized on a homing heading, it is possible to determine the heading relative to the initial homing heading reference, and this data can be used similarly to heading gyro data. It is anticipated that the accuracy of the heading information derived from a heading gyro will be somewhat poorer than that derived from a rate gyro. However, the rate gyro will not accrue the precession error inherent in a directional gyro. The precession rates of typical directional gyroscopes lie between 0.5 to 4.0 degrees per minute.

The integrated output from a rate gyroscope that is periodically corrected by the output form a flux gage transducer, is another possible method of instrumenting the heading measurement. The rate gyro choice eliminates the necessity to cope with the precession associated with heading gyros. The heading information stored in the registers of of the data processor can be corrected by data obtained from the flux gate transducer during intervals when the rate gyro output is small, indicating a low rate of turn and a small bank angle at which time the accuracy of the flux gate transducer is high. During update, the previous heading data stored in the registers is dumped and replaced by the flux gage transducer's output. Between updates, the integrated output of the rate gyro is continuously summed to the contents of this register to generate the current inertial heading.

One other difficulty encountered in using gyroscopes is the time required for the spin motor to reach operating speed. Intervals between one and five minutes are typical. This requires initiating the run-up prior to air deployment, or delaying active guidance until the required run-up interval has elapsed. Pre-deployment run-up implies a manually operated switch with the attendant passibility that it will not be activated because of human error, or the use of an automatically disconnected umbilical cord connected to the aircraft power source.

As observed by the sponsor in his instrumented guidance package, a directionally stabilized instrument package may be required to secure meaningful directional data. The random rotations of the unstabilized instrument package introduced perturbations into the directional data that make meaningful calculations difficult or impossible. However, by using a drag stabilized instrument package, this problem can be eleminated.

It was also suggested that the payload and instrument package could be combined into a single container. This appears feasible, and adopting this concept will also eliminate variations in the receiving antenna system performance that can result from electromagnetic energy reflecting from a conductive payload suspended below the antenna.

2.5.1.1.2.2 Magnetic. - A magnetic compass is also a potentially useful instrument for measuring the heading of the airdrop system. Its primary disadvantage is the directional error that results when its axis deviates from the vertical. This error is known as tilt error, and its magnitude is a function of the tilt angle and the magnetic latitude as shown in figure 16. Gimbal stabilization is ineffective for this application because the coordinated turns prevent using gravity stabilization.*

Figure 3 of Goodrick's Report** reproduced as figure 17, shows the bank angle variation for a typical optimal trajectory of the airdrop system. Inspection of this illustration shows that the bank angle is less than three degrees for 72 percent of the flight, and it never exceeds seven degrees. Obviously, this data does not include the extreme altitudes assumed during deployment.

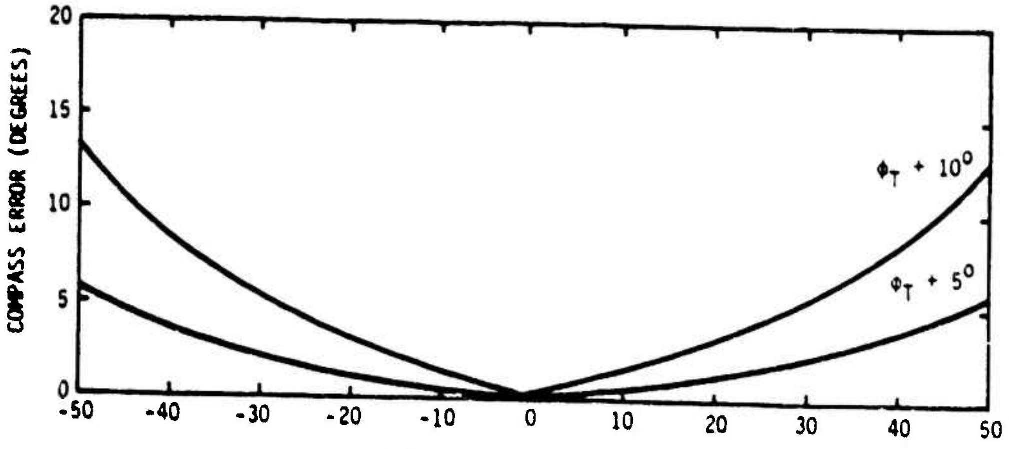

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Figure 16. Magnetic Compass Maximum Tilt Error Versus Magnetic Latitude

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*Scheiber, Donald J., "Methods of Compensating a Solid State Compass So As to Reduce the Error Due to Tilting to a Minimum, and the Significance of the Residual Tilt Error", Magnavox Report, 30 April, 1965, Fort Wayne, Ind.

**Goodrick, et al.

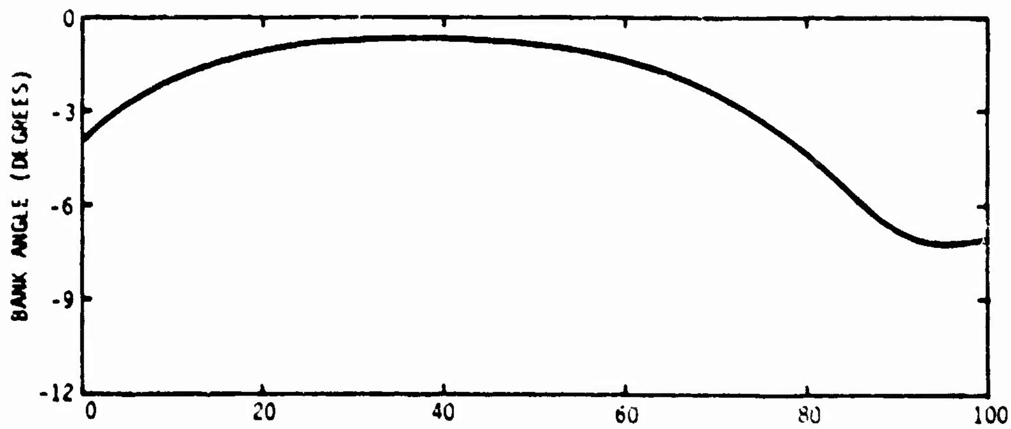

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Figure 17. Bank Angle Variation for Typical Optimal Trajectory

Inspection of figure 16 shows that at latitudes of less than 45 degrees, the error from a three-degree tilt will not exceed seven degrees. The larger error occurs during the final segment of the flight where the range has been reduced, and the effect of a given heading error is likely to produce a smaller position error.

In view of the following advantages of a flux-gate type magnetic sensor, it appears to be an optimal instrument to measure heading:

(1) It does not require spin-up time

(2) It will not tumble and does not require caging or uncaging

(3) It provides a heading referenced to magnetic North, and does not require a period of homing flight to establish a homing heading reference

(4) It is not subject to precession error

(5) It is relatively inexpensive and light weight

Its disadvantages are the following:

(1) It exhibits tilt error when its vertical axis is inclined

(2) It is influenced by the presence of magnetic material or isolated DC current carrying wires in its vicinity

(3) Its indication is influenced by local variation.

One suitable instrument is King Radio Corporation's Magnet Azimuth Transmitter Model KMT 112. This is a flux gate transducer. It is 8.55 cm in diameter by 4.6 cm high. It weighs 136 grams. It requires a power source of 26 volt, 400 Hz. Its accuracy is specified to be within two degrees of the local magnetic heading. Bendix Avionics and other make similar instruments.

2.5.1.1.3 Altitude. - The two techniques most commonly used to measure altitude are barometric and radar altimeters. The first measures altitude above a reference, normally sea level, by the change in atmospheric pressure. The radar altimeter measures the elevation above local terrain by processing a transmitted signal that is reflected from the terrain immediately below the antenna. Either technique appears suitable and one tends to complement the other; radar low altitude high accuracy; barometric high altitude less accurate.

Barometric and Radar types can measure altitudes to the maximum 20,000 foot altitude specified in the system description. Numerous tranducers are available that are suitable.

2.5.1.1.3.1 Barometric Altimeters. - One disadvantage of the barometric type is that it is referenced to sea level rather than to local terrain. In calculating trajectories, the above ground level (AGL) altitude is of importance since it is this altitude that determines remaining flight time. If the area is well charted, the MSL altitude of the drop zone (DZ) can be determined from maps. The ground party can also radio this information to the aircraft, and the airdrop altimeter can be adjusted prior to drop to indicate AGL altitude. One other means of correcting the altitude to AGL is to include an altimeter in the ground station beacon transmitter, encode this altitude information, and transmit it to the airborne unit. In the airborne unit, the decoded altitude information is processed to correct the indicated altitude to AGL.

A Rosemount Type 1241M Barometric Transducer appears to be suitable for this application. Its accuracy characteristics are shown in figure 18, and additional details are included in Appendix E. Its calibration is limited to 15,000 feet and its error increases rapidly beyond this altitude as shown in figure 18. However, when the airdrop package altitude is at this extreme altitude, it is probable that a larger error can be tolerated.

A second similar instrument is manufactured by Computer Instruments Corporation and designated either Model 8000 or Model 8200. Its altitude maximum is 35,000 feet and its accuracy is specified as 0.25 percent of altitude +20 feet. Its characteristics are also included in Appendix E.

2.5.1.1.3.2 Radar Altimeter. - A radar altimeter measures the altitude of its antenna(s) above the terrain immediately below it. Its maximum useful altitude extends to 70,000 feet. Both pulse and frequency modulations are used, but pulse types are more common. Honeywell Avionics Division

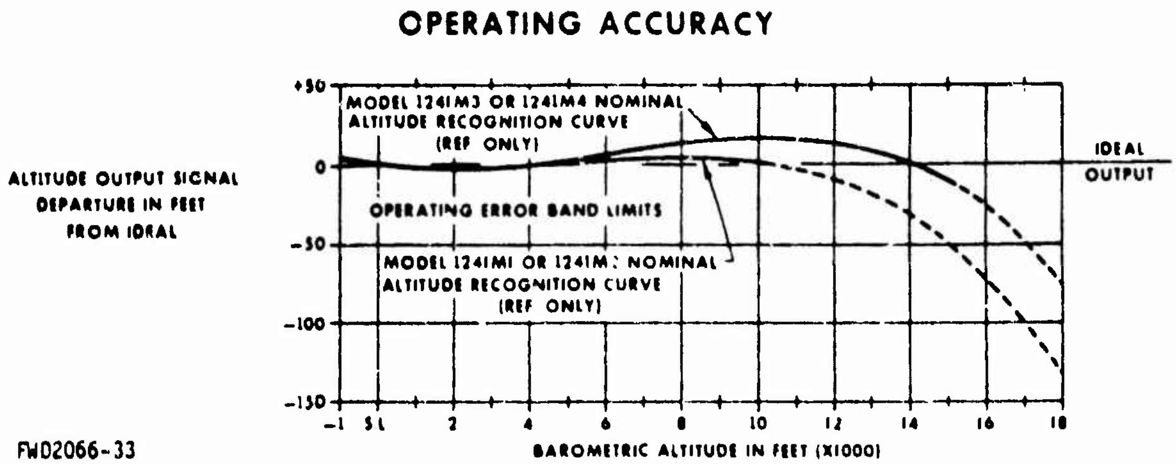

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Figure 18. Altitude Accuracy of Rosemount 1241M Barometric Transducer

has built prototype units that provide accuracies of ±5 feet (+ 0.5%) at all altitudes. Its estimated cost is approximately $10,000.00 in reasonable quantities. Unfortunately, it is not in production and will not be until a sizeable order is secured.

A low cost radar altimeter is manufactured by Bonzer, Inc., but its maximum altitude is limited to 2,500 feet. Its accuracy varies from five feet below 100 feet to ' percent of altitude above 500 feet. Its cost is approximately $700.00.

Because of the maximum altitude restriction of most of the low cost units, a radar altimeter is usually used in conjunction with a barometric altimeter. Whether or not dual instrumentation is required is determined by the accuracy required during the terminal phases of the flight. If 5 to 25 feet accuracy is needed for altitudes below 500 feet, the radar altimeter can provide that precision. The primary advantage of a radar altimeter is that its indication of altitude is AGL eliminating the need to correct for local elevation.

2.5.1.1.4 Airspeed. - The horizontal airspeed of the airdrop unit is approximately 12 meters per second (42.2 km/per hour or 22.8 knots), consequently, conventional aircraft instrumentation is unsuitable for these low speeds. There are three instruments that perform well in this airspeed range; hot wire, ion displacement and vortex shedding anemometers. All are small and sufficiently accurate. Ranges from 0.01 to 500 meters per second are available, and accuracies lie between two and ten percent. All types must be carefully mounted to ensure that its placement measures the actual airspeed of the airdrop unit.

The vertical airspeed of the airdrop unit is approximately four meters per second. Although the altitude rate (rate of decent) can be obtained from the altitude measurements, it may prove advantageous to measure the vertical airspeed. Variometers used with sailplanes fulfill this need very nicely. One suitable sensor made by Ball Engineering Company has a full scale range of approximately five meters per second (1000 ft./min.). The anemometers used to measure horizontal airspeed can also satisfy this requirement.

The two primary contenders for airspeed sensors are the Thermo Systems, Incorporated, Model 201 Cross Wind Sensor, and J-Tech Associates, Inc., Model 220 Airspeed Sensor. Both have been militarized.

The Model 201 Cross Wind Sensor was designed for use in the fire control system for the XM-1 Main Battle Tank. Its velocity range is from 0 to 20 m/s and its stated accuracy is ±0.5 m/s ±10 percent. For use in this application, it must be rotated 90 degrees from its normal orientation to provide a readout of the airspeed. Since its output voltage is proportional to the product of the wind velocity and the cosine of the angle of arrival, it requires that a drag stabilized guidance system be used to ensure that the resultant airspeed including the side-slip components is measured. It is a relatively large sensor, 8.25 x 56 cm, and its cost is estimated at $4,800.00 each at the end of 1979 and $1,800.00 each at the end of 1980.

The Model 220 sensor was designed for helicopter applications. Its velocity range is from 2 to 200 knots (1.02 to 102 m/s), and its stated accuracy is one percent of full scale, or approximately ±1 m/s. It can measure without additional error, winds up to ±20 degrees off-axis. Goodrick's* simulation showed that the maximum sideslip angle of the payload will not exceed this angle. The significance of this characteristic is that unless required by other sensors, the payload and guidance package will not require drag stabilization. The cost of this sensor is approximately $990.00 in small quantities.

Hot wire anemometers are also suitable. However, suitably packaged, ruggedized instruments were not located during this study although they most probably exist.

2.5.1.1.5 Homing Deviation Angle. - All of the guidance techniques discussed require measurement of homing deviation angle. The complexity required for the various approaches ranges from homing with an output approximately linear with deviation angle over a sector near boresight to full ADF (automatic direction finding) with accurate deviation angle measurements over the full 360 degree azimuth range.

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*Goodrick 73-462

Although there are various approaches to homing and direction finding, the simplest and most common technique utilized is to generate cardioid-shaped patterns which are sequentially lobed with a pattern maximum to the left and then to the right of boresight. An amplitude modulated signal results (see figure 17) which is characterized by the following: (a) The modulation frequency is determined by the frequency of the lobing oscillator, (b) the percent modulation is proportional to heading deviation angle, and (c) the phase relative to the lobing oscillator is either zero or 180 degrees depending upon whether the source is left or right of boresight. The resulting modulated signal is then demodulated and processed in a synchronous detector with the original lobing signal as shown in figure 18 and the resulting signal is proportional to homing deviation angle. The lobing frequency is optional and can be selected based on system requirements such as receiver characteristics.

Magnavox has designed and built homing equipment for a variety of systems ranging from shipboard to airborne, including gliding airdrop applications. These units have covered frequencies ranging from MF through UHF.

Three different methods of generating an AM homing signal (demodulated by an AM receiver) are shown in figure 19. A cardioid pattern can be formed by spacing two monopoles a quarter wavelength apart and phasing them 90 degrees as shown in figure 19a.

Lobing is accomplished by switching the feed and termination ports of the hybrid. This is the most efficient method and has been used successfully at VHF and UHF frequencies, but the physical dimensions become unmanageable for this application at lower frequencies. The "towel bar" antenna approach shown in figure 19b utilizes a transmission line antenna which generates an approximate cardioid pattern when fed at one end and terminated at the other end. Efficiencies are not as great as the previous method described, but much smaller elements can be used, and patterns can be controlled by proper selection of termination impedances. The method most commonly used at low frequencies (in the HF spectrum) is shown in figure 19c and consists of properly combining a loop antenna (figure "8" pattern) with a monopole (omidirectional) to provide a cardioid homing pattern. Although the methods discussed provide amplitude homing, phase front homing is possible* (for utilization with FM receivers) by simple modification to the homing RF receiver.

2.5.2 CHMS Guidance System

A simplified block diagram of the primary CHMS guidance system is shown in figure 20. The details of each of its major assemblies are addressed in subsequent paragraphs of this section.

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*Davis, Bruce W., and Soldutti, Andrew R., Phase Front Homing. ECOM Report 4727, November 1974. U. S. Army Electronics Command, Ft. Monmouth, N.J.

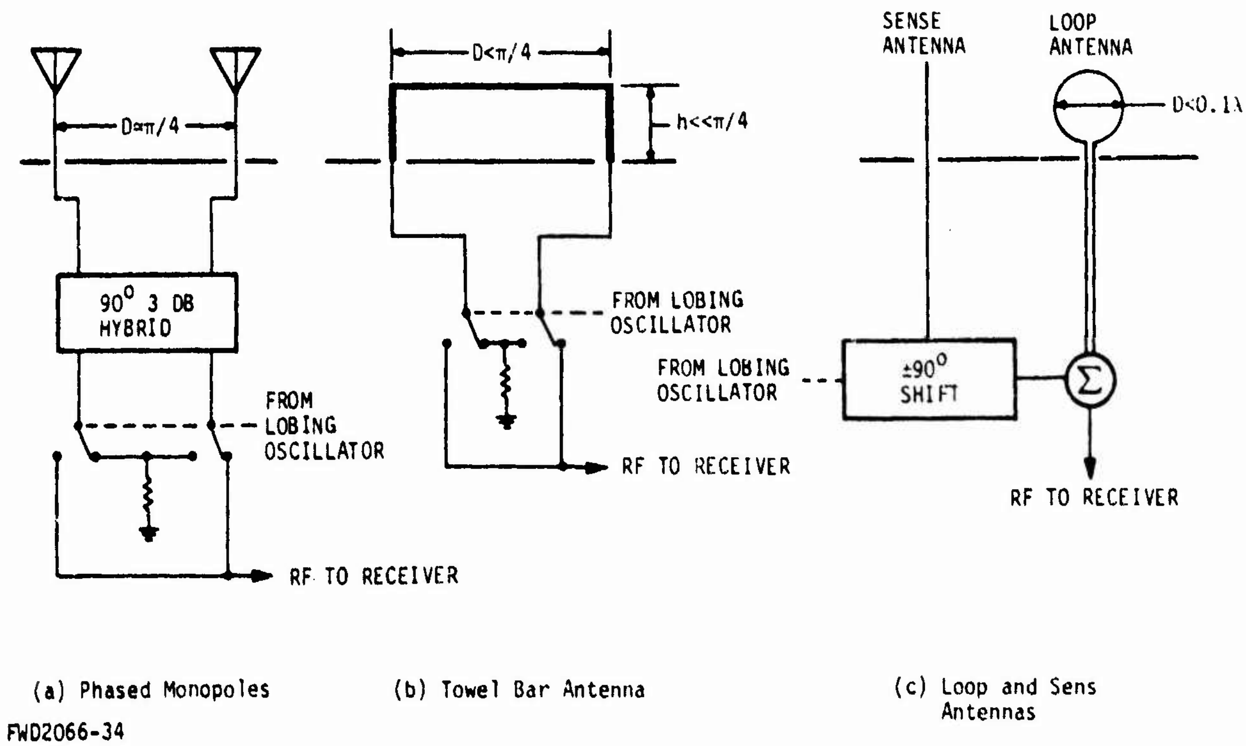

Figure 19. Three Methods of Generating AM Homing Signals

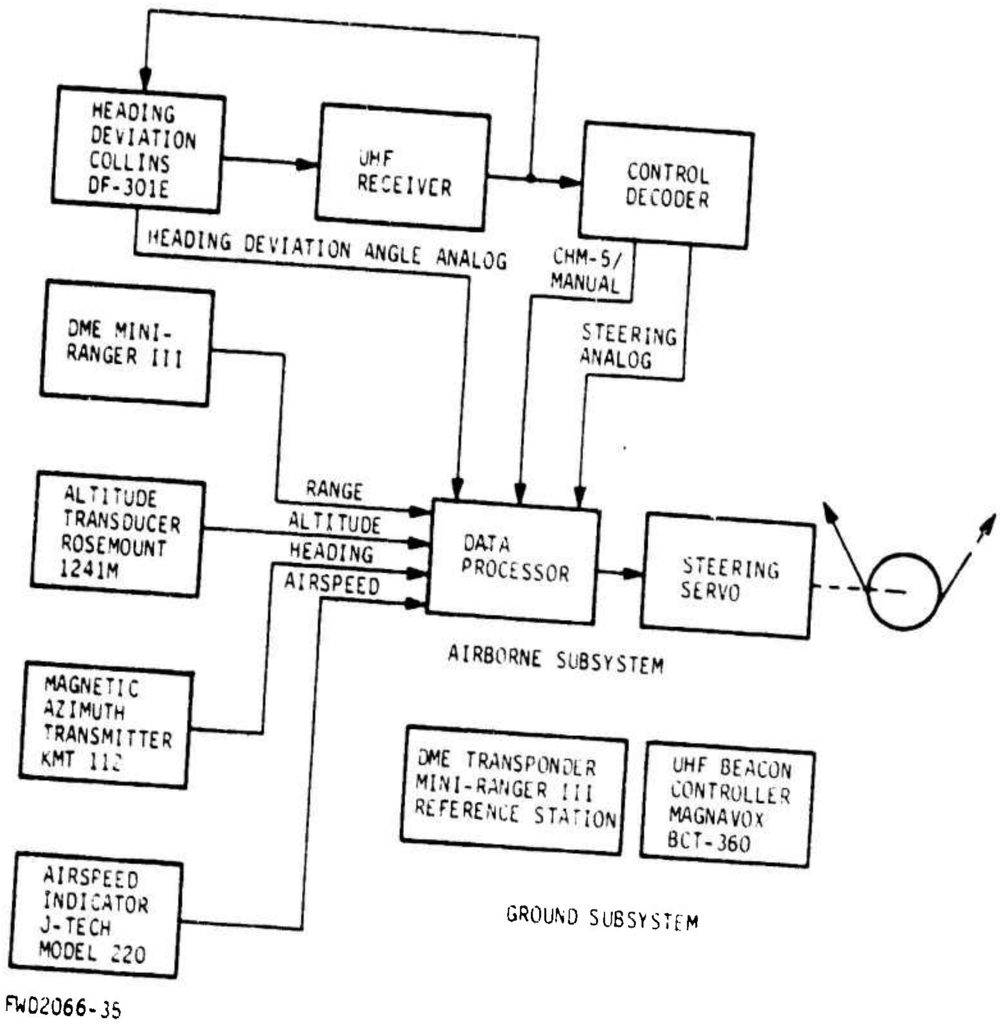

Figure 20. CHM5 Primary Guidance System Mini-Ranger III Ranging

2.5.2.1 Primary System

2.5.2.1.1 Airborne Subsystem. - The Airborne Subsystem consists of the following principal assemblies:

(1) Antennas
(2) UHF Receiver
(3) Sensor Subsystem
(4) Data Processor
(5) Control Decoder
(6) Servo Actuator
(7) Primary Power Source

The functional divisions are completely separate. For example, the ADF antenna forms a part of the Heading Deviation Sensor, but it is also used for the reception of manual control commands from the ground subsystem. Some of these assemblies are also used in other guidance systems previously described in this document. The newly introduced assemblies will be described in detail, but those previously described will only be referenced.

2.5.2.1.1.1 Antennas. - Two antennas are required for the airborne subsystem: DME and ADF. The DME operates in the 5400 to 5600 MHz range, and the ADF in the 225 to 400 MHz band. Both antennas should ideally provide hemispherical radiation patterns.

There are two antenna options available with the Mini-Ranger III DME. One provides hermispherical coverage and is identified by part number 85-24336E01. Its gain is not specified, but it should theoretically be 3 dB. The other antenna is omnidirectional in azimuth, its vertical beamwidth is 25 degrees and its gain is specified as 6 dB. Its part number is 85-P04917F001.

The maximum range of the Mini-Ranger III is specified as 19 km when 6 dB antennas are used at both ends of the link. Assuming that the hemispherical antenna provides a gain of 3 dB and that this antenna is used at both ends of the link, the maximum useful range of the system will be reduced to one-half that specified when two 6 dB antennas are used, or a maximum range of 9.5 km may be anticipated. Since the reduced range is less than the maximum range of 14.2 km specified, the use of the 6 dB antenna is highly desirable.

To determine whether or not the 6 dB antenna can be used requires detailed knowledge of its vertical pattern. It is highly probable that satisfactory system operation can be achieved at high elevation angles if the 6 dB antenna's sidelobe amplitude is not too low. If operation with two 6 dB antennas is not possible, perhaps, using a hemisperical antenna with the ground station, and a 6 dB antenna with the airborne subsystem will provide the desired high angle coverage while reducing the maximum range to 13.5 km. If the hemispherical antennas must be used at both the airborne and ground, a reduction in the maximum range to 9.5 km appears to be necessary compromise.

The ADF Antenna is an integral part of the ADF Assembly. It consists of an eight-segment antenna that produces an electronically rotated cardioidal antenna pattern. It also contains an integral preamplifier with 17 dB gain and a 6 dB noise figure. A more detailed description of this assembly is included in Appendix E. The ADF antenna is also used as the receiving antenna when the system is operating in the manual control mode.

2.5.2.1.1.2 UHF Receiver. - The UHF Receiver is identical to the one described in subsection 2.2.2.3. The audio output from the receiver forms the error signal to the DF-301E ADF and the input to the Control Decoder during manual control operation.

2.5.2.1.1.3 Sensor Subsystem. - The following parameters must be measured by the Sensor Subsystem:

(1) Heading Deviation Angle
(2) Range
(3) Altitude
(4) Inertial Heading
(5) Airspeed

Each of these sensors was discussed in subsection 2.5.1.1. Additional information is provided here.

2.5.2.1.1.3.1 Heading Deviation Angle. - The Heading Deviation Angle Sensor is a Collins Radio ADF, Model DF-301E. A brief product description of this sensor is included in Appendix E. It provides an RF output to the UHF Receiver and requires an audio input from the UHF receiver for phase comparison with its internal 5.68 KHz reference voltage, to determine the direction of arrival of the signal. The Heading Deviation Angle signal is a standard synchro output which must be further processed by the Data Processor.

In addition to the RF and Audio inputs, the DF301E also requires 27 Vdc and 27 V, 400 Hz inputs. The 400 Hz will be supplied by a small DC to 400 Hz inverter.

2.5.2.1.1.3.2 Range. - Range between the Airborne and Ground subsystems is measured by the DME components of the Motorola Mini-Ranger III navigation system. Basic range measurement is accomplished by a Receiver-Transmitter and a Range module. An option is required to permit it to generate a unique interrogate code, and to process only replies to its own interrogations. The Four Code Module listed in figure 11 may not be the exact module required to accomplish this function, but it is representative of the complexity required, and its cost should be similar. A standard Mini-Ranger III Range Module is used to convert the elapsed time between interrogation and reply into distance in meters between the airborne and ground subsystems.

2.5.2.1.1.3.3 Altitude. - The altitude sensor is a Rosemount Model 1241M Altitude Transducer. It is characterized in subsection 2.5.1 and additional details are included in Appendix E.

Perhaps the simplest way to translate the MSL indication of the Altitude Transducer into AGL altitude is to manually inset the drop zone altitude into the airborne unit to permit the Data Processor to compute the AGL altitude. This can also be accomplished automatically by encoding the output form an altitude transducer located at the DZ and modulating it on an up-link to the airborne subsystem.

2.5.2.1.1.3.4 Inertial Heading. - The inertial heading sensor is a magnetic azimuth transmitter manufactured by King Radio and designated Model KMT-112. It is actually a flux gate transducer as decribed in subsection 2.5.1.1. It requires 26 V, 400 Hz input power source which it will share with the DF-301E. Its output must be processed by the Data Processor similarly to that of the DF-301E ADF.

2.5.2.1.1.3.5 Airspeed. - The airspeed sensor is a J-Tech Model 220 Airspeed Sensor. Its accuracy is approximately one m/s. It is powered from the standard 28 Vdc source. Its output of 50 mv/knot (97 mv/m/s) is large enough for easy processing. It also is more fully described in Appendix E.

2.5.2.1.1.4 Data Processor. - The primary function of the data processing section of the gliding airdrop system is to process the measured input parameters in accordance with a chosen guidance scheme, and to compute the desired value of a key steering parameter. This task must be accomplished by a high performance, moderately complex design that is compatible with the cost and performance goals of a modern gliding airdrop system. In addition, the data processor should have the flexibility to manage the CHM5 or Directed Radial Homing Full State Specification Schemes and those partial state schemes that require processing.

A microprocessor-based design represents a sound solution to the processing element of the system. This design approach provides the capability of incorporating all of the features necessary for a cost effective, high performance subsystem. Some of the outstanding features of this approach are listed below.

- Programmable
- Moderate complexity
- High reliability
- Easily assembled
- Low power
- Low cost

The programmability feature of this design approach offers a high degree of design and operational flexibility at all levels of product development. For example, a basic system can be designed and programmed to exercise one of the full state specification schemes and then, reprogrammed to perform other full state schemes. Furthermcre, this flexibility is especially useful in the later stages of development because many costly hardware changes can be eliminated by making software changes.

Programmability along with the other features mentioned can be realized with a system based on a standard, general purpose microprocessor.

A special purpose processor could also be employed in the system. However, the additional development cost probably would not result in an appreciable improvement in performance. Therefore, a data processing subsystem based on a general purpose microprocessor or controller with a few other standard components represents an optimal relationship between cost and performance.

A simplified block diagram of the data processing subsystem is shown in figure 21. The major functions of the system are the central processing unit (CPU), memory, analog-to-digital converter (A/D), digital-to-alanog converter (D/A), and calculator device. The CPU is the controlling element of the system. It generates the timing and control signals for the other major functions. The sequential operation of the CPU is determined by the stored program in the memory. The memory serves as both a temporary and permanent data storage area. The program instructons and fixed reference tables are stored in Read-Only-Memory (ROM) and temporary data is stored in Random-Access-Memory (RAM). The D/A's and A/D's are the INPUT/OUTPUT devices. They provide the electrical interface between the analog measuring and steering control devices and the processing unit. Finally, the calculator device may be used to perform the more complicated mathematical computations such as square root, trigonometric functions, multiply, and divide. However, the calculator device is not absolutely necessary. That is, the multiply, divide and square root operations can be done with a set of software algorithms. And, the trigonometric function can be implemented with a SINE/COSINE table stored in ROM. Both approaches will give good performance. The first approach using the calculator device would be faster and more accurate; however, the extra speed and accuracy might not be needed.

The basic processing operations of this design concept are initialization, data acquisition, computation, and steering data output. During initialization all of the variable reference data is loaded into RAM memory for later reference during the computational process. The reference data may be selectable from the front panel, or internally presettable. After the initialization sequence, the system is now ready to perform the other functions.

First, the analog signals, which represent a measured parameter, are sequentially routed through the analog multiplexer to the A/D converter. The processor controls the multiplexer control line, thus it determines which sensor output will be seen at the output of the multiplexer. Now, the output of the multiplexer is applied to the A/D converter. In response to a signal from the processor, the A/D starts its conversion cycle. When the conversion is complete, the A/D outputs a conversion-complete signal to the processor.

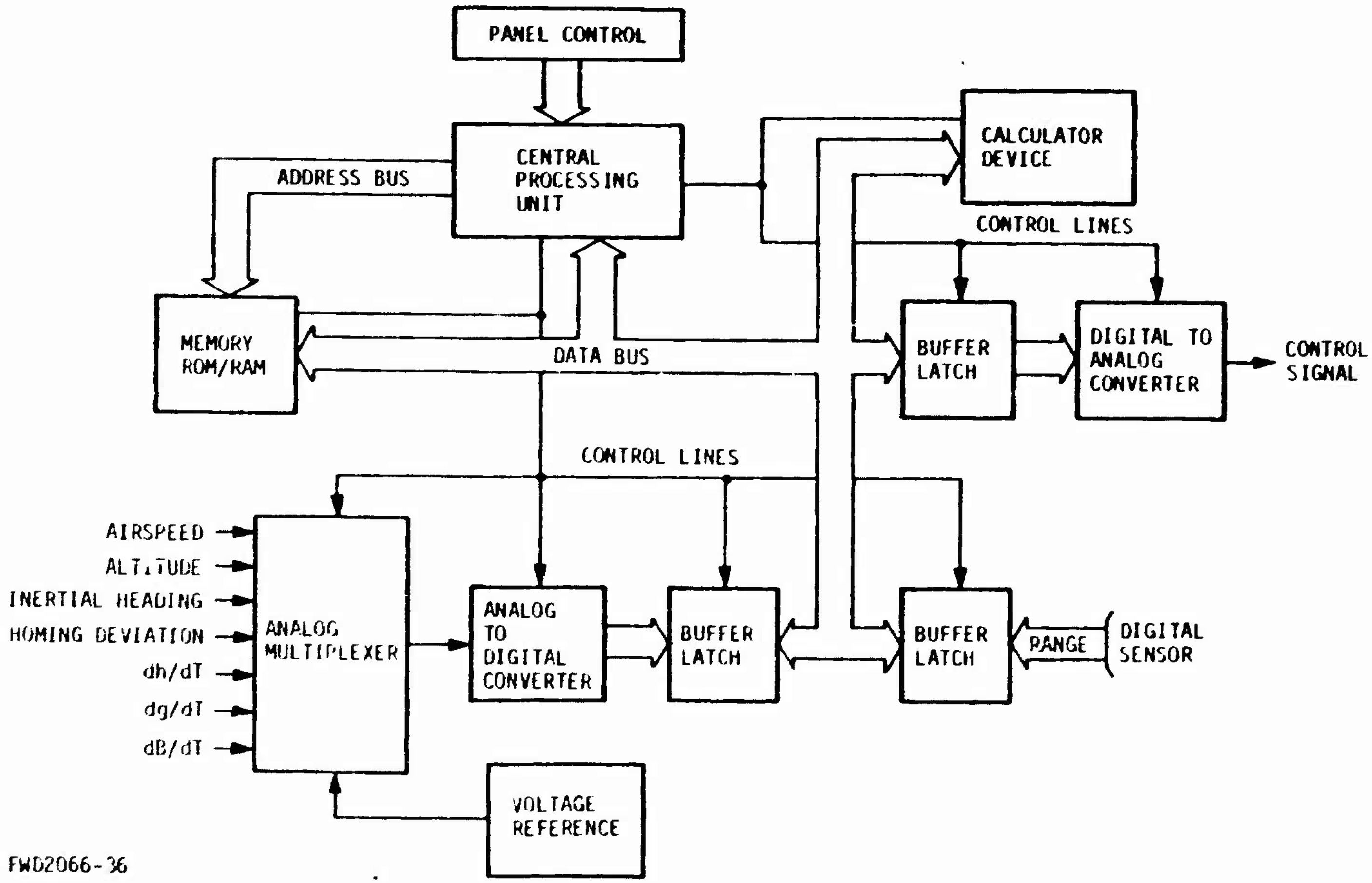

Figure 21. Data Processor Block Diagram

The processor then reads the converted data via a tri-state buffer and stores it in memory. Also, if a sensor device has a binary output, the sensor data is read directly through a dedicated input port. Immediately after the variable data is assembled in memory, the processor is ready to compute the steering parameter. This parameter will be computed using an algorithm based on one of the guidance schemes.

When the key steering parameter has been calculated, the binary representation of the parameter is loaded into a output buffer latch. The output of the latch is applied to a D/A converter. The D/A converts the binary input to a voltage equivalent. This voltage output is used to drive the steering control circuit. This entire process of data acquisition, computation and steering control is repeated throughout the flight to attain an accurate, upwind landing.

The hardware implementation of the microprocessor design approach makes it possible to place most of the complexity of processing in firmware (programmed PROM's). The major functions as well as the support logic can be done using low power CMOS technology. For instance, the now commonly used RCA CDP1802 CMOS microprocessor is a good candidate for the processor. This device has the processing capability for this application. Also, CMOS versions of other popular processors such as INTEL'x 8048 and 8085, Texas Instruments' TMS1000, and Motorola's 6800 will soon appear on the market. These will also make excellent candidates for this system.

The anticipated power consumption of the Data Processor is less than 0.5 watts. The number of memory components required for this system is determined mainly by the stored program. It is estimated that about 1500-2000 8-bit bytes of software will be required. This means that two 1k x 8 ROM and two 256 x 8 RAM will be sufficient for this system.

2.5.2.1.1.5 Control Decoder. - The Control Decoder is described in Section 7.0 of AGS-500 Airdrop Guidance Manual included as Appendix B to this document. The same decoder can be used in all guidance systems that include manual override. It must be modified to provide proportional pitch control.

2.5.2.1.1.6 Servo Actuator. - The Servo Actuator differs for each payload capacity system. Designs for 500, 2000, and 15000 pound payloads are detailed in subsection 2.2.2.5.

2.5.2.1.1.7 Primary Power. - The Primary Power Source for the airborne unit is batteries. Providing separate battery supplies for the servo and electronic portions of the guidance package appears to be an optimal method of minimizing Electromagnetic Interference (EMI) problems. Lead Acid batteries appear to be most cost effective. Batteries are discussed in subsection 2.2.5.3.1.

2.5.2.1.2 Ground Subsystem. - The ground subsystem for CHMS Guidance is relatively simple. It consists of a DME transponder used to measure range, and a UHF Beacon Controller that provides the source for homing and the link through which manual control of the airborne unit is exercised.

The Transponder is the reference unit of the Mini-Ranger III navigation system. To accomodate multiple airborne units operating simultaneously, a Multi-User option must be added. The same comments concerning the antenna are appropos. Using the 6 dB antenna is highly desirable to ensure achievement of the maximum desired range. However, it is possible that a combination of a hemispherical antenna used with the Ground subsystem, and a 6 dB antenna used with the airborne subsystem would be a suitable compromise. This combination reduces the maximum range capability to 0.7 that provided by two 6 dB antennas, but will provide significantly greater signal amplitude at high elevation angles. The anticipated range for the hemispherical/6 dB antenna combination is 13.4 km versus the desired 14.. km.

The Beacon Controller is the BCT-360 described in Appendix B. It provides 400 mw RF power and manual control steering and step input pitch control of the airdrop unit.

Both components of the ground station are powered from a rechargeable batteries.

2.5.2.1.3 Cost Summary. - A summary of the cost for a CHMS Guidance System for payloads of 500, 2000 and 15000 pounds is given in table 17.

2.5.2.2 Alternate Guidance System. - A simplified block diagram of an alternate, lower cost, lower performance guidance system is shown in figure 22. Many of its components are identical to those used in the primary system. The major difference between the primary and alternate systems is the methods used to measure range and Homing Deviation Angles. Range is estimated from antenna tilt angle when HDA is within 30 deg.

2.5.2.2.1 Airborne Subsystem. - The airborne subsystem contains many of the same functional blocks as the primary system. However the antennas and the heading deviation sensor differ from those used in the primary system and range is not measured directly; it is computed from depression angle and altitude.

2.5.2.2.1.1 Antennas. - Two antennas are required by the alternate system: Depression Angle Antenna and the Homing Deviation Angle antenna. Because the depression angle measurement requires the use of a loop antenna, its upper operating frequency must be limited to the HF frequency range. To allow the use of the same beacon transmitter for both angle measuring functions, the homing deviation angle sensor must operate at the same frequency. In conformance with the intent to use off-the-shelf components insofar as possible, a commercial aircraft LF-MF ADF is immediately suggested as the homing deviation angle measuring device.

Table 17. CHM5 Primary Guidance System
Medium-Quantity Cost Summary - Configuration I

Item	Cost		
	Payload capacity pounds		
	500	2,000	15,000
Airborne Subsystem			
Heading Deviation Sensor	$ 2,756	$ 2,756	$ 2,756
DME	7,158	7,158	7,158
Altitude Transducer	700	700	700
Inertial Heading Sensor	200	200	200
Airspeed Sensor	1,000	1,000	1,000
UHF Receiver	200	200	200
Control Decoder	100	100	100
Data Processor	1,200	1,200	1,200
Electronics Batteries	30	30	30
Subtotal	$13,344	$13,344	$13,344
Steering Servo and Batteries	544	1,200	2,197
Total	$13,888	$14,544	$15,541
Ground Subsystem			
BLT-360 Beacon-Controller	$ 524	$ 524	$ 524
Mini-Ranger Transponder w/ Multi-User Option	5,164	5,164	5,164
Total	$ 5,688	$ 5,688	$ 5,688

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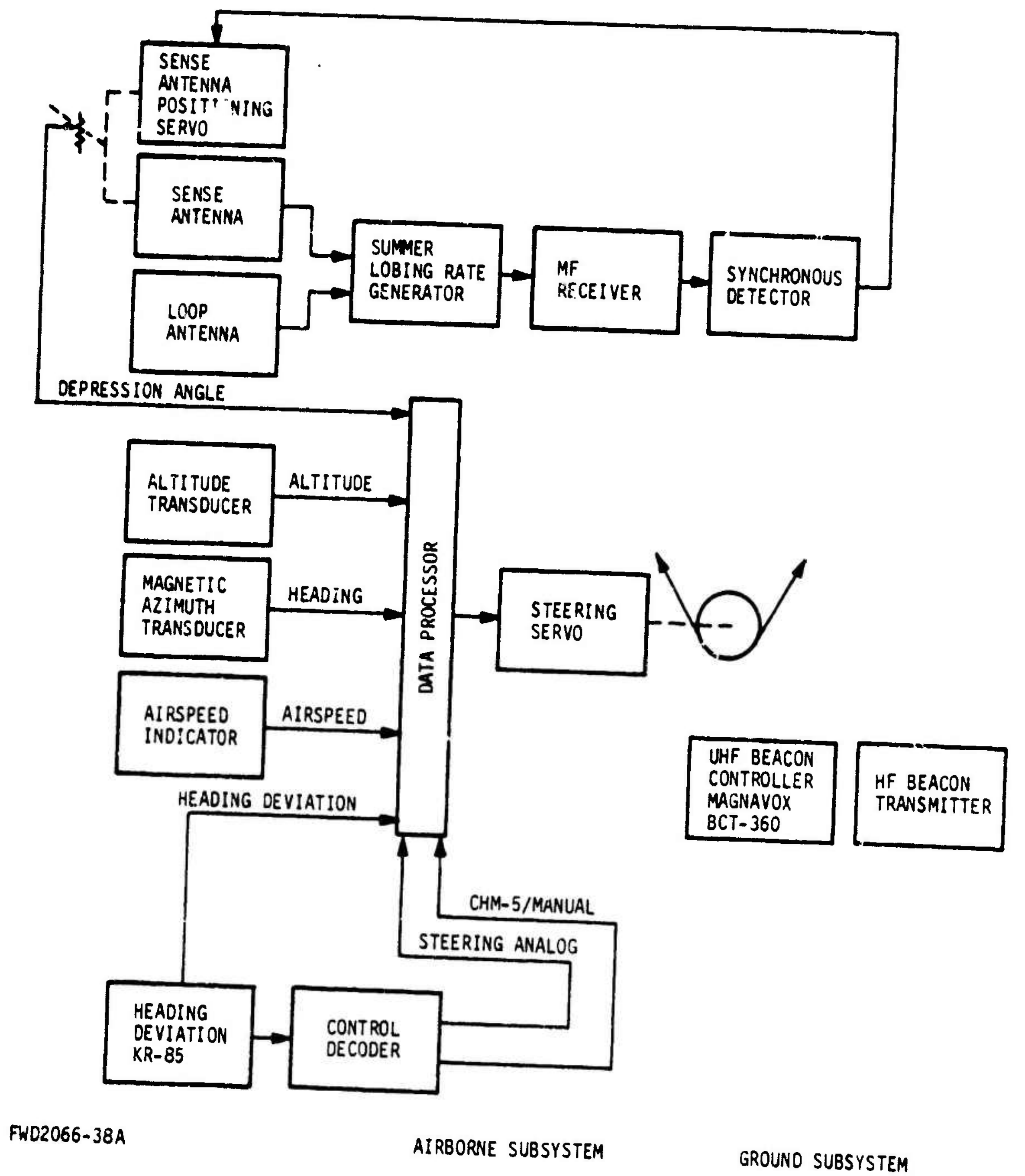

Figure 22. Alternate Guidance Subsystem Altitude-Depression Angle Ranging

The upper frequency limit of commercial ADF equipment is 1750 KHz. This is a practicable frequency range and Magnavox has built and flown numerous cargo delivery homing systems that operate in this frequency range. Its primary disadvantage is the relatively large transmitting antenna required to secure adequate efficiency. A compensating advantage is the lower path loss per km that occurs at the lower frequency. Availability of commerical equipment establishes the operating frequency of the alternate guidance system in the MF band near 1750 KHz.

The depression angle measurement technique is described in subsection 2.4.2. For this application, the location of the sense antenna must be varied by a servo actuator until a phase reversal is detected. A position feedback potentiometer develops a DC voltage proportional to the sense antenna position on its ground plane, which, in turn, is a voltage analog of the depression angle to the beacon transmitter. A subroutine in the data processor is required to correct the depression angle measurement for heading deviation angle error introduced by the ground plane shape.

The depression angle measuring antenna consists of a short sense antenna, its positioning servo, a loop antenna, and a summing and lobing module that combines the outputs of these two antennas.

The antenna used to measure homing deviation angle is a part of a standard aircraft ADF such as King Radio Model KR-85 which is suitable and typical. The antenna consists of a loop and a sense antenna combined into a single unit and is identified as model KA-42B. The sense antenna must exhibit very small antenna tilt to be suitable for this application. Consequently, it must be mounted symmetrically on its ground plane.

2.5.2.2.1.2 Receivers. - Two MF receivers are required: one each for the depression angle and the homing deviation angle measurement sensors. It is possible to time share these functions using a single receiver, but it is not clear that the added switching complexity and the increased interval between samples is a satisfactory tradeoff. Consequently, a separate receiver is assumed necessary for each function.

The receiver required for the depression angle sensor is conventional in all respects. It must provide a sensitivity of approximately -100 dBm for 10 dB S + N/N, and requires an AGC time constant that is long compared with the lobing interval. These requirements, except for its operating frequency of 1750 KHz, are identical to those of the UHF receiver previously described.

The receiver proposed for the heading deviation angle sensor is a part of the ADF, which also includes the synchronous detector, the lobing generator, and the sense and loop antenna combining circuitry.

2.5.2.2.1.3 Homing Deviation Angle Sensor. - This sensor consists of the King Radio KA-42 combined loop and sense antenna, and the electronics assembly which derives directional information from the antenna inputs.

The entire assembly is designated Model KR-85. Its heading output is a standard synchro signal proportional to the relative bearing of the signal source. This synchro output requires further processing by the data processor to transform its format into a digital word that is suitable for further computation.

2.5.2.2.1.4 Other Sensors. - The other sensors required (altitude, heading, and airspeed) are identical to those required by the primary system. Sensor requirements differ only for Range and Heading Deviation Angle.

The Range is determined by computation from the measurement of the depression angle and the altitude as described in subsection 2.5.1.1.1. Heading deviation angle measurement is accomplished similarly to the primary system, except that it is done at MF instead of UHF, to be compatible with the antenna system required for the depression angle measurement sensor.

2.5.2.2.1.5 Servo Actuator. - The specific servo actuator required is a function only of the payload capacity of the system and is unaffected by the guidance technique used. Consequently, the discussions of subsection 2.2.2.5.3 is completely applicable to the alternate guidance system.

2.5.2.2.1.6 Primary Power. - Nothing in the alternate approach significantly alters the primary power requirements from those of the primary guidance system.

2.5.2.2.2 Ground Subsystem. - The Ground Subsystem as shown in figure 2-21, consists of a MF Beacon transmitter modulated by a control encoder to effect manual guidance control over the airborne subsystem. The major differences between the primary and the alternate beacon transmitter are the operating frequencies, the transmitting antennas and power levels required because of the differing operating frequencies, and effective gains of the airborne antenna systems.

The transmitting antenna efficiency is directly related to its length, but the convenience of its use is the inverse of this dimension. However, 10 to 15-foot whips are readily available in the Army's inventory and have proven to be satisfactory. Consequently, this type of antenna is suggested for this application. If base loaded, its efficiency may be anticipated to be approximately 0.1 percent. This suggests a minimum RF power input of 228 milliwatts. The atmospheric noise to be expected at MF (worst case) is 9.28 dB above 1 μv/m or 2.88 μv/m. The minimum transmitter RF power should be increased by an order of magnitude to a minimum of 3 watts to ensure that a satisfactory signal-to-noise ratio exists at the receiving antennas.

The ground beacon will consist of a crystal-controlled transmitter whose frequency can be changed by replacing the frequency determining crystal. With only slightly more complexity and cost, a frequency synthesizer can be provided that eliminates the necessity for plug-in crystals. The overall efficiency of the ground beacon is estimated to be

20 percent, suggesting an input power requirement of 15 watts. If a 12-volt battery is used, a current requirement of 1.25 amperes is required. To provide four hours of operation at room temperature requires a battery capacity of 6 AH. Its life is approximately halved when operating at -20 degrees C.

The same manual control encoder described in conjunction with the BCT-360 UHF Beacon Transmitter in Appendix B, is suitable for use with this ground beacon.

2.5.2.2.3 Alternate Guidance System Small Quantity Cost Summary. - A summary of the estimated costs of the alternate systems with payload capacities of 500, 2,000 and 15,000 pounds is shown in table 18.

Table 18. Alternate Guidance System Medium-Quantity Cost Summary

Item	Cost		
	Payload capacity pounds		
	500	2,000	15,000
Airborne Subsystem			
Depression Angle Sensor Antenna	$ 400	$ 400	$ 400
Medium Frequency Receiver	150	150	150
Synchronous Detector	25	25	25
Heading Deviation Angle Sensor	1,695	1,695	1,695
Control Decoder	100	100	100
Altitude Transducer	700	700	700
Inertial Heading Sensor	200	200	200
Airspeed Sensor	1,000	1,000	1,000
Data Processor	1,200	1,200	1,200
Electronics Batteries	30	30	30
Subtotal	$5,500	$5,500	$5,500
Steering Servo and Batteries	554	1,200	2,197
Total	$6,044	$6,700	$7,697
Ground Subsystem			
Beacon Transmitter with Antenna, Control Encoder and Batteries	$1,000	$1,000	$1,000

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APPENDIX A

MEASURED ARRAY
AND
SINGLE ANTENNA PATTERNS
FOR THE
ADR-500/U

APPENDIX A

This appendix presents the measured array and single antenna patterns of the ADR-500/U. In addition to the principal plane patterns, azimuth patterns at depression angles to 75 degrees are included. The pattern index is tabulated below.

Pattern No.	Description
1	Array, Azimuth, 0 degree depression angle
2	Array, Azimuth, 0 degree depression angle
3	Array, Azimuth, 20 degree depression angle
4	Array, Azimuth, 20 degree depression angle
5	Array, Azimuth, 45 degree depression angle
6	Array, Azimuth, 45 degree depression angle
7	Array, Azimuth, 60 degree depression angle
8	Array, Azimuth, 60 degree depression angle
9	Array, Azimuth, 75 degree depression angle
10	Array, Azimuth, 75 degree depression angle
11	Array, Elevation, Left-Right
12	Array, Elevation, Left-Right
13	Array, Elevation, Fore-Aft
14	Single Antenna, Azimuth, 0 degree depression angle
15	Single Antenna, Elevation, Left-Right
16	Single Antenna, Elevation, Fore-Aft

THE **Magnavox** COMPANY

SHEET 1 OF 16

ANTENNA ADR 500/U ARRAY

PROJECT [illegible]

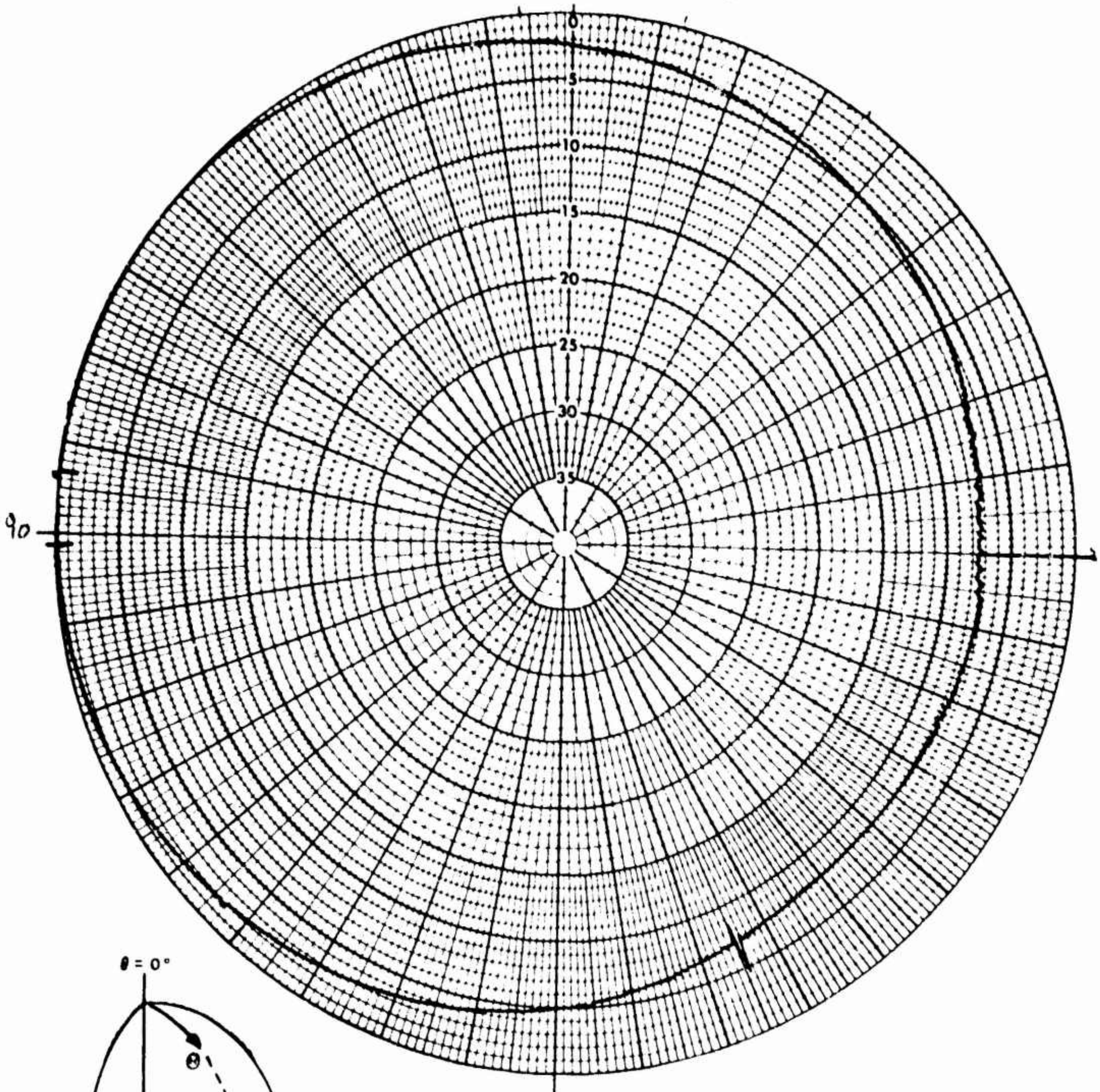
REMARKS [illegible]

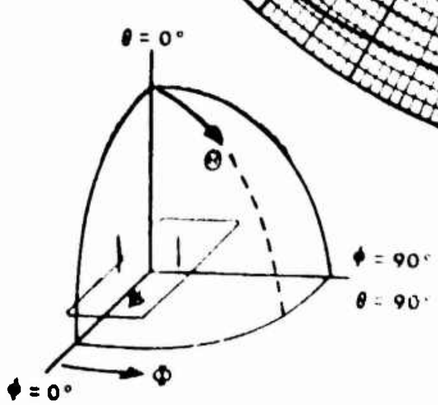
0° DEPRESSION ANGLE

SCALE [illegible] SCALE FREQ [illegible]

DATE [illegible]

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ E_θ ✓

VARIABLE ANGLE Φ ✓ Θ

CONSTANT ANGLE ϕ = θ = 90°

TECH [illegible] ENGR [illegible]

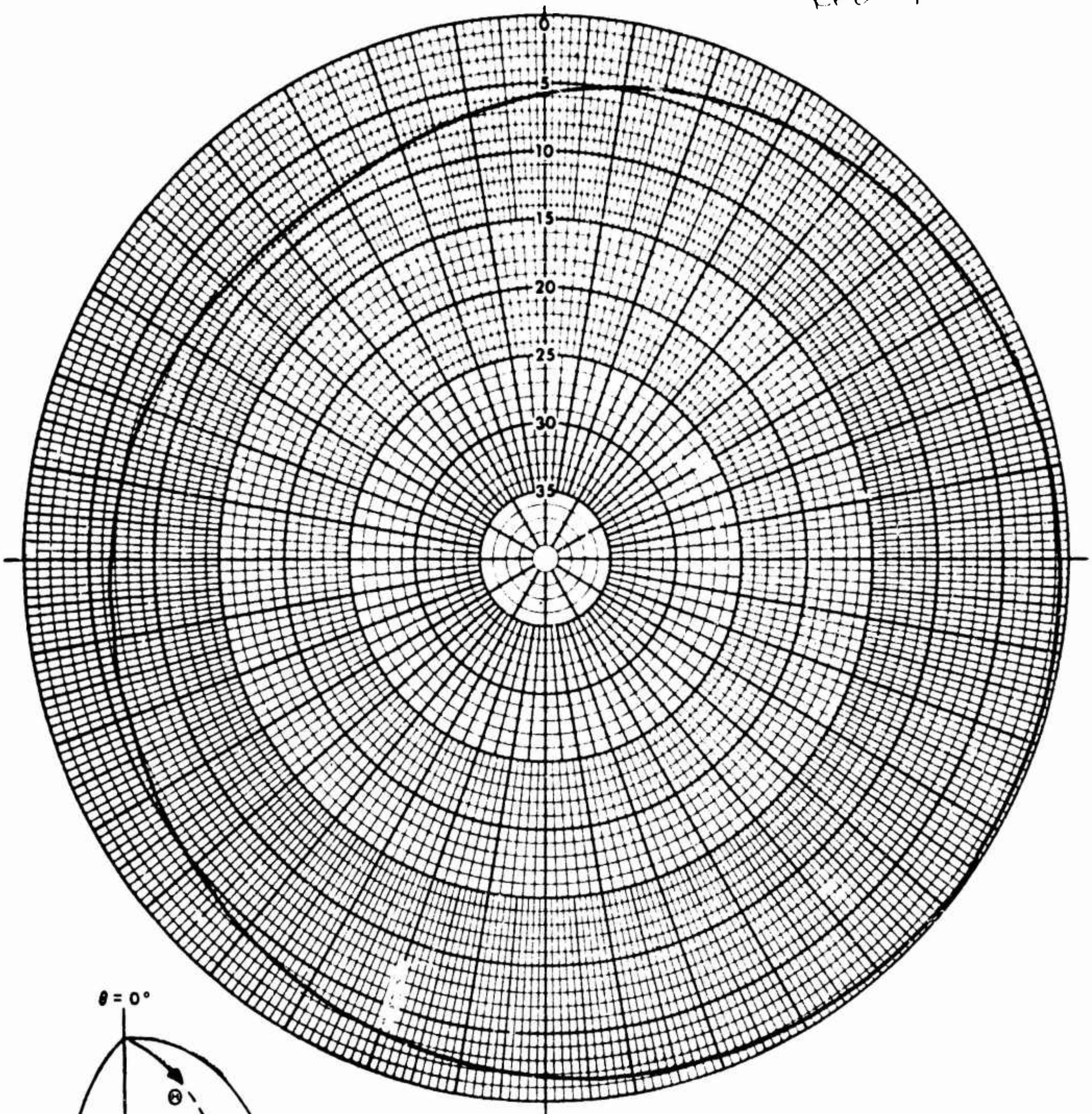
THE **Magnavox** COMPANY

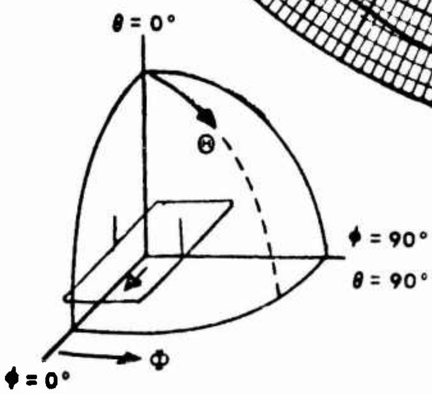
SHEET 2 OF 16

ANTENNA ADK-300/11 ARRAY	SCALE FULL SCALE FREQ. [illegible]
PROJECT 64941	DATE 6-14-73
REMARKS AZIMUTH	
0° DEPRESSION ANGLE	

POLAR RECORD (40 DB RANGE)

Rev 1





POLARIZATION E_ϕ ___ , E_θ ✓ , ___	
VARIABLE ANGLE Φ ✓ , Θ ___	
CONSTANT ANGLE ϕ = ___ , θ = 90	
TECH ___	ENGR ___

THE **Magnavox** COMPANY

SHEET 3 OF 16

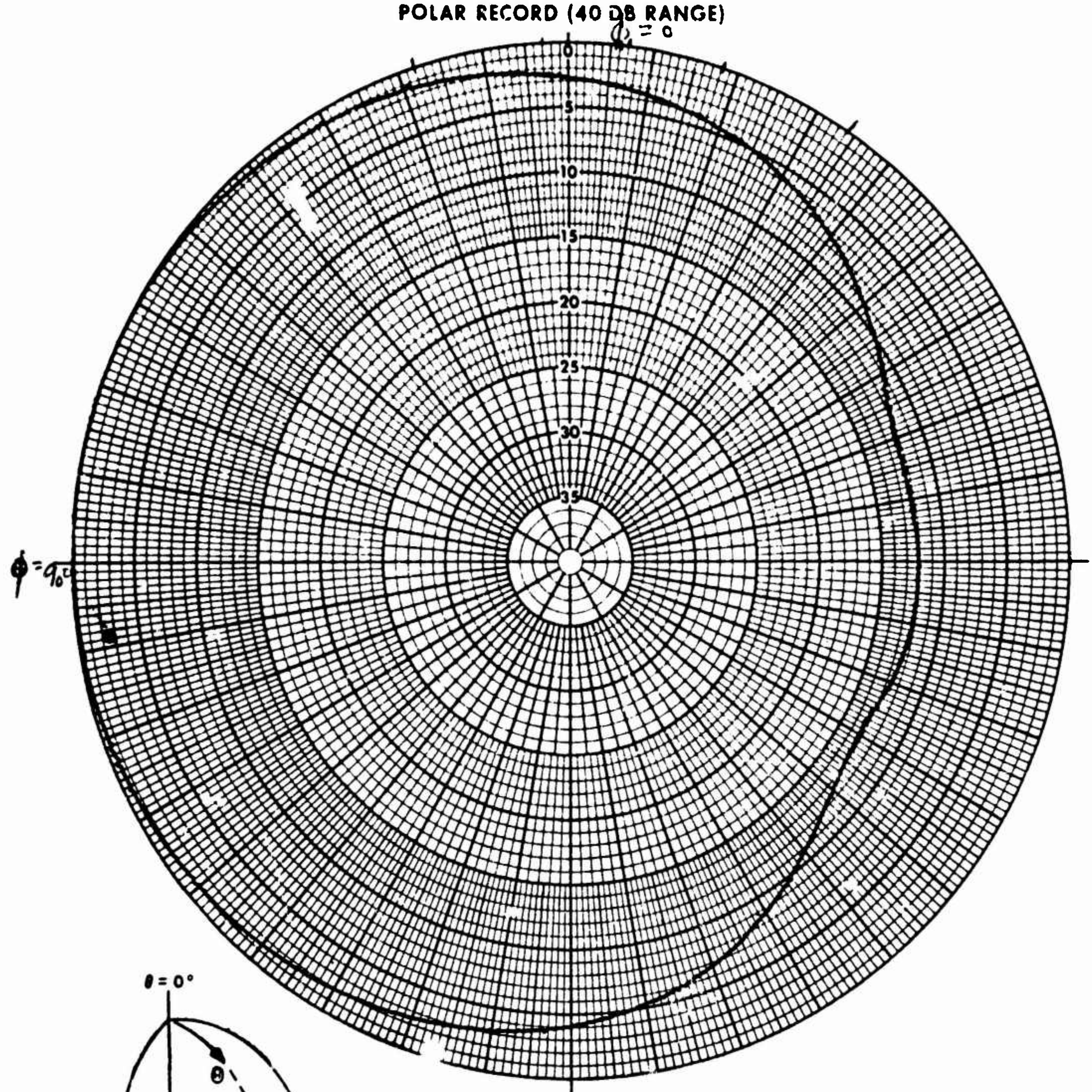
ANTENNA ADR-500IU ARRAY SCALE FULL SCALE FREQ [illegible] MHz

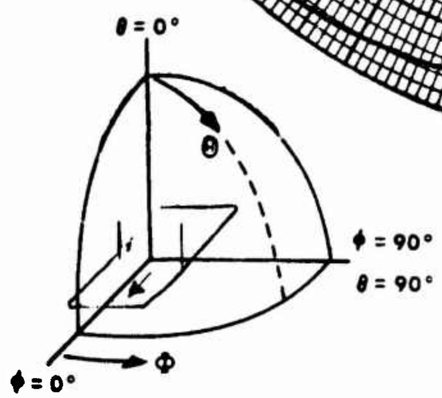
PROJECT [illegible] DATE [illegible]

REMARKS AZIMUTH

20° DEPRESSION ANGLE

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ ____, E_θ ✓, ____

VARIABLE ANGLE Φ ✓, Θ ____

CONSTANT ANGLE φ = ____, θ = 70

TECH ____ ENGR ____

THE **Magnavox** COMPANY

SHEET 4 OF 10

ANTENNA 4' ... ARRAY

PROJECT 4941

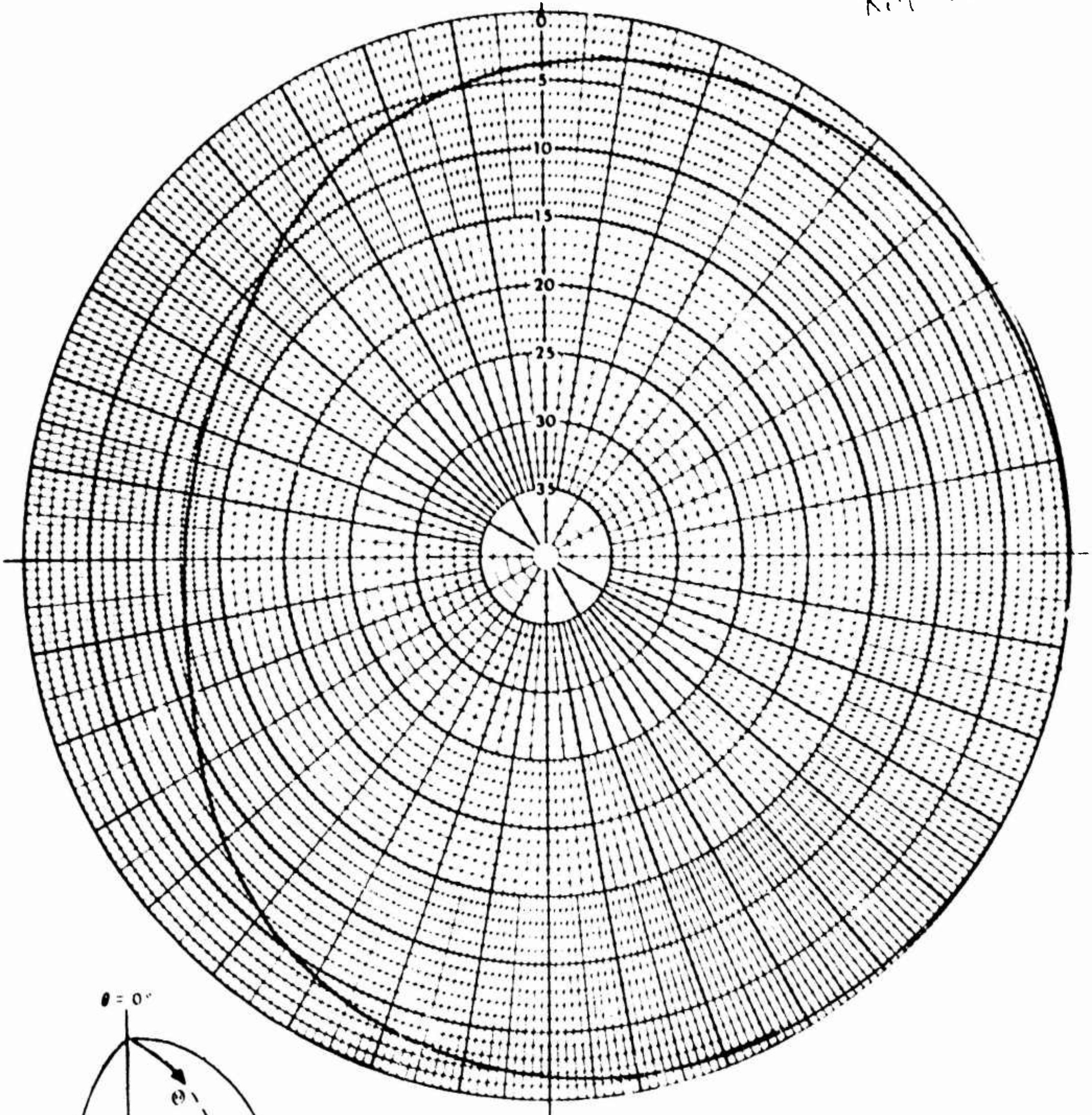
MARKS AZIMUTH

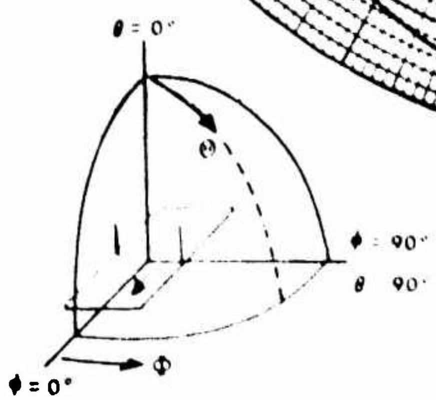
... PRECISION ANGLE

SCALE ... SCALE FREQ

DATE

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ	E_θ	
VARIABLE ANGLE Φ		Θ
CONSTANT ANGLE φ		θ 10
TECH	ENGR	

THE **Magnavox** COMPANY

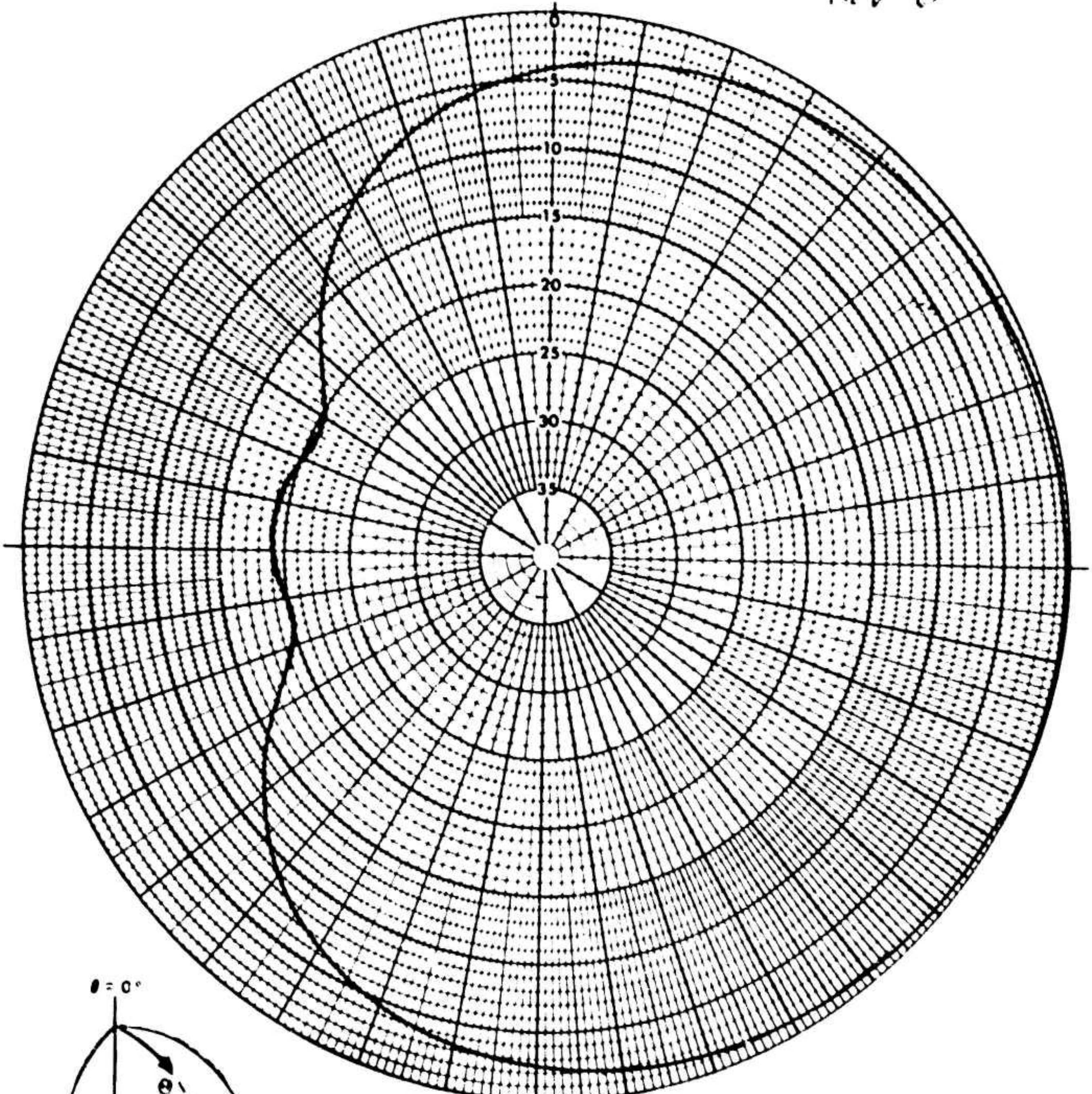
SHEET 5 OF 16

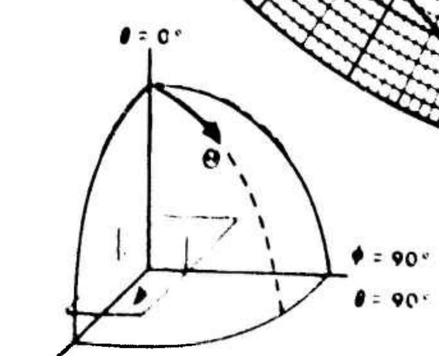
ANTENNA
PROJECT
REMARKS
45° DEGREE

SCALE SCALE FREQ
DATE

POLAR RECORD (40 DB RANGE)

Rev 6





POLARIZATION E_ϕ E_θ V

VARIABLE ANGLE Φ V Θ

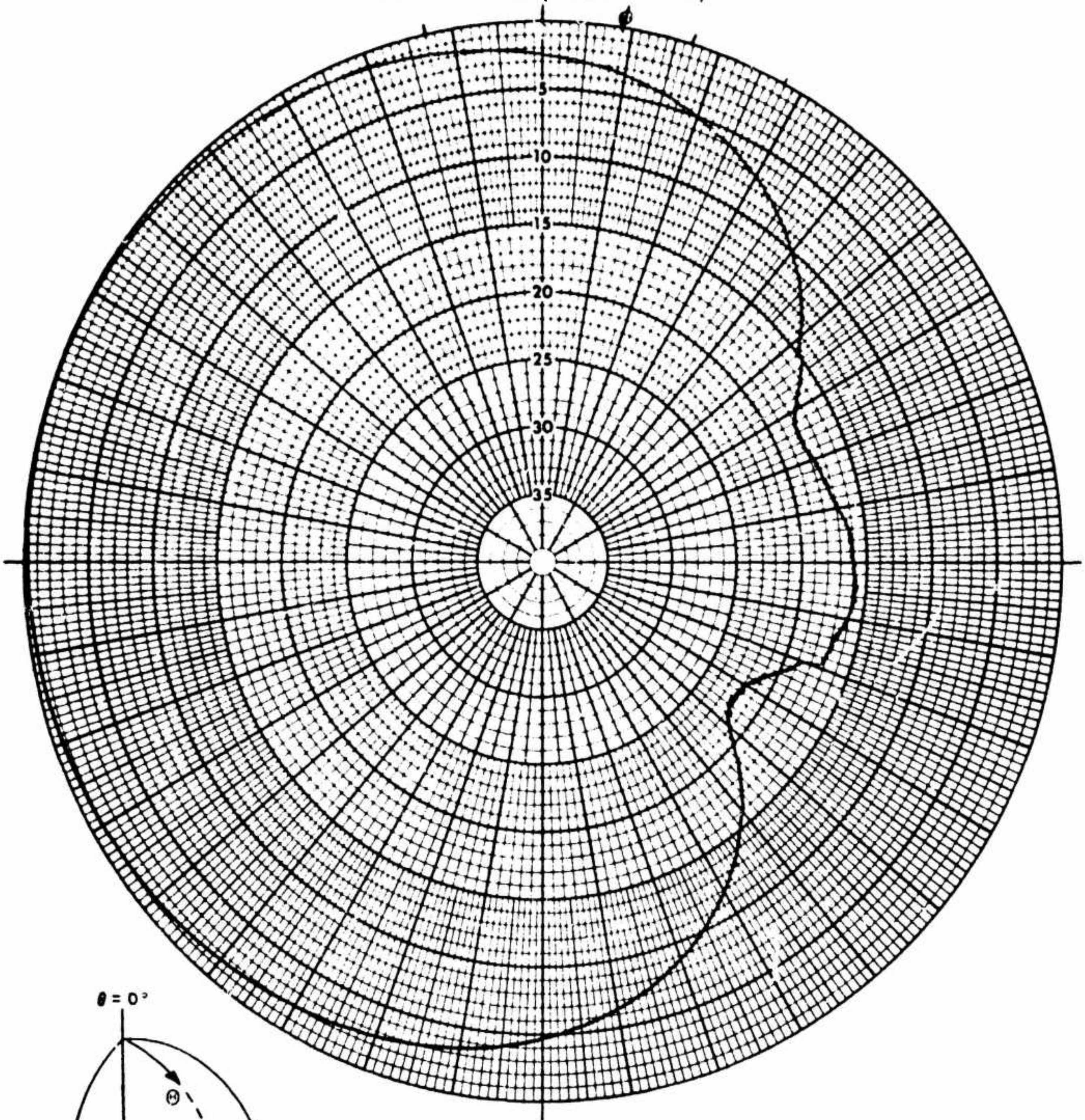
CONSTANT ANGLE ϕ = θ =

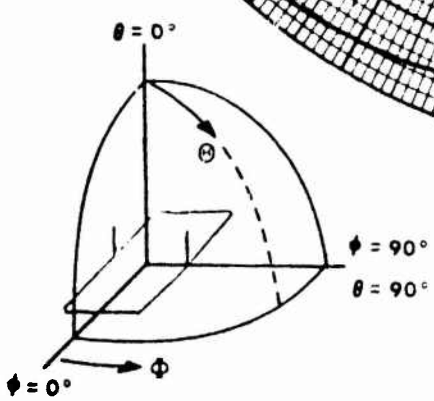
TECH ENGR

THE **Magnavox** COMPANY SHEET 6 OF 16

ANTENNA	ADF Loop Array	SCALE [illegible]	SCALE FREQ 362
PROJECT	64941		DATE 6-14-73
REMARKS	A [illegible]		
	45° DEPRESSION ANGLE		

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ ___ , E_θ ✓ , ___	
VARIABLE ANGLE Φ ✓ , Θ ___	
CONSTANT ANGLE ϕ = ___ , θ = 45°	
TECH ___	ENGR ___

THE **Magnavox** COMPANY

SHEET 7 OF 16

ANTENNA ADR-500/U ARRAY

SCALE FULL SCALE FREQ. ____

PROJECT 64941

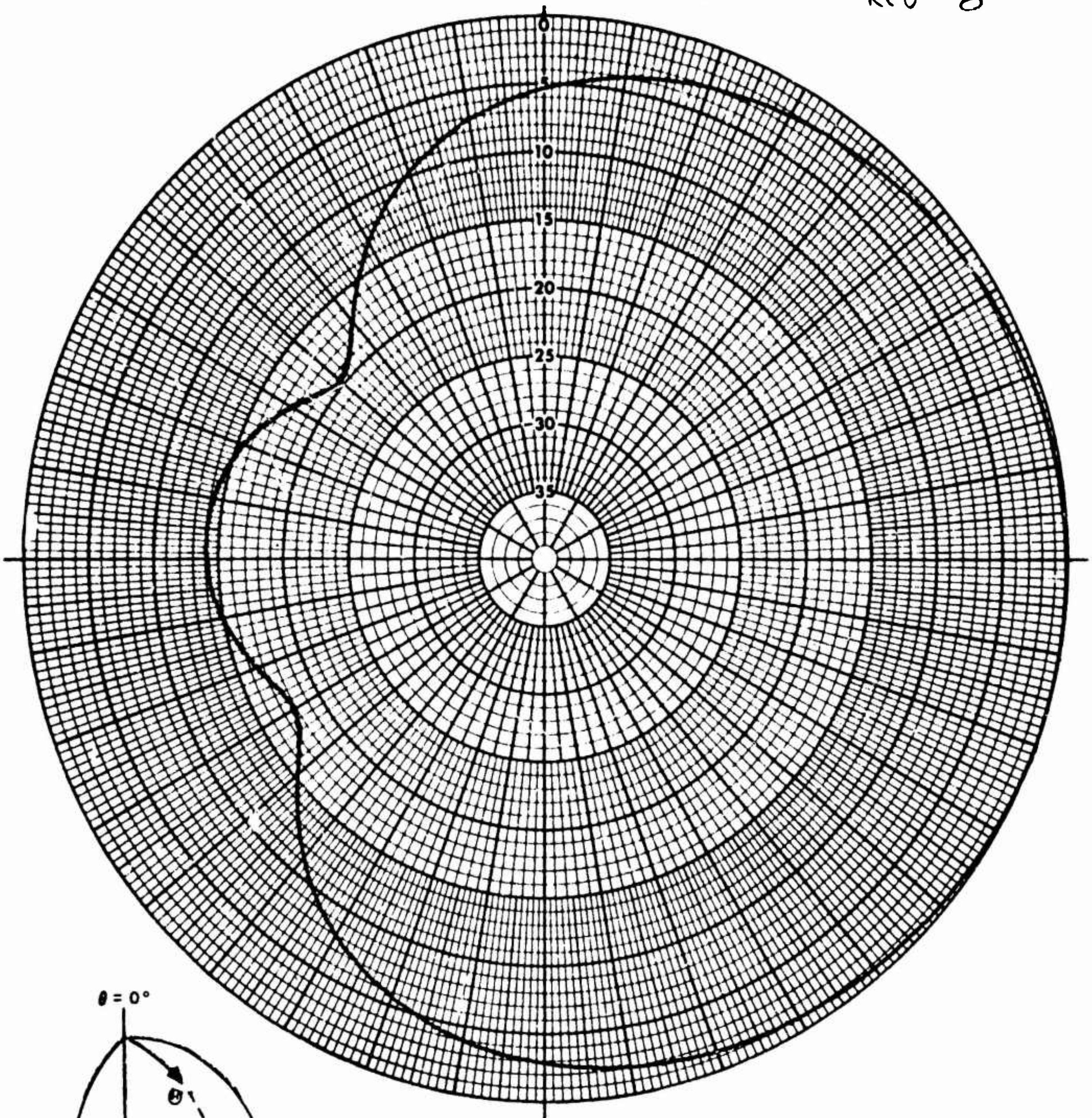
DATE 6-14-73

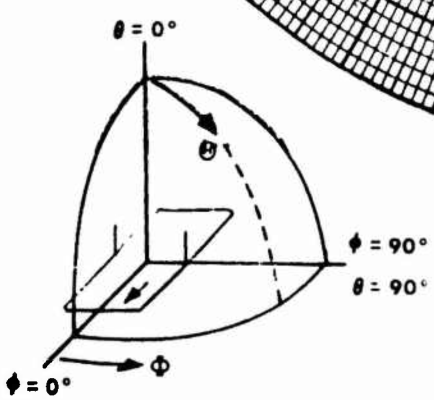
MARKS AZIMUTH

60° DEPRESSION ANGLE

POLAR RECORD (40 DB RANGE)

Rev 8





POLARIZATION E_ϕ ____, E_θ ✓, ____

VARIABLE ANGLE Φ ✓, Θ ____

CONSTANT ANGLE ϕ = ____, θ = 30°

TECH ____ ENGR ____

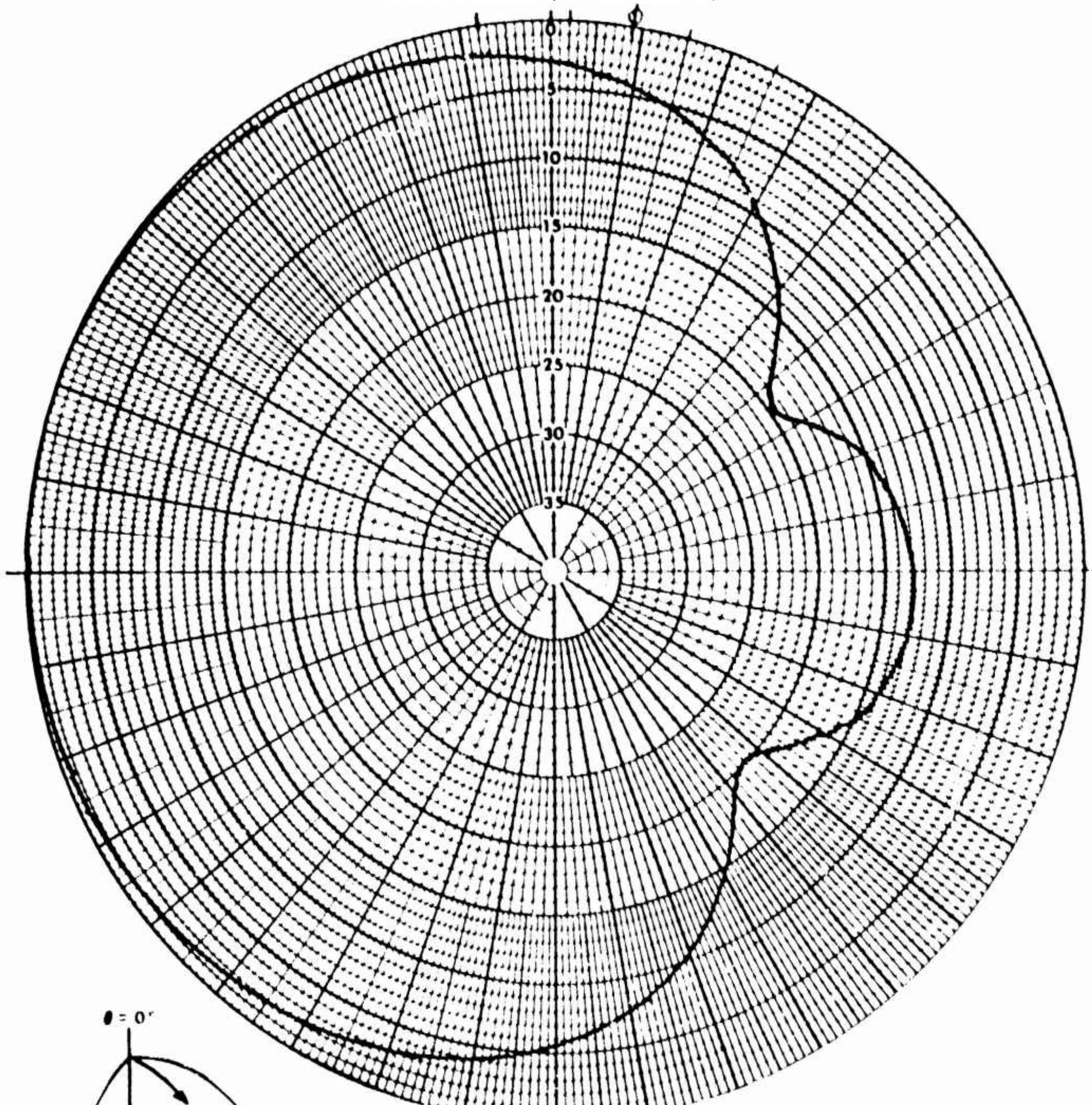
THE **Magnavox** COMPANY — SHEET 8 OF 16

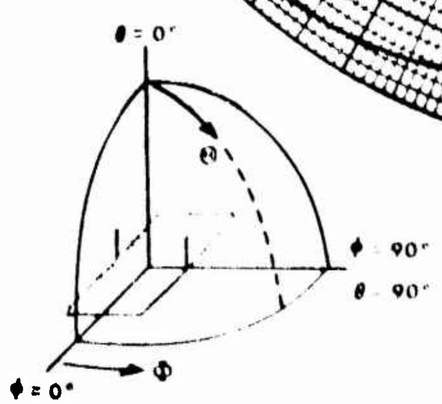
ANTENNA ADF 500 ARRAY — SCALE LINE — SCALE FREQ

PROJECT 64941 — DATE

MARKS AZIMUTH
60° DEPRESSION ANGLE

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ E_θ

VARIABLE ANGLE Φ Θ

CONSTANT ANGLE ϕ θ

TECH ENGR

THE **Magnavox** COMPANY

SHEET 9 OF 16

ANTENNA ADR-500/U ARRAY SCALE Bill SCALE FREQ 362.5 MHz

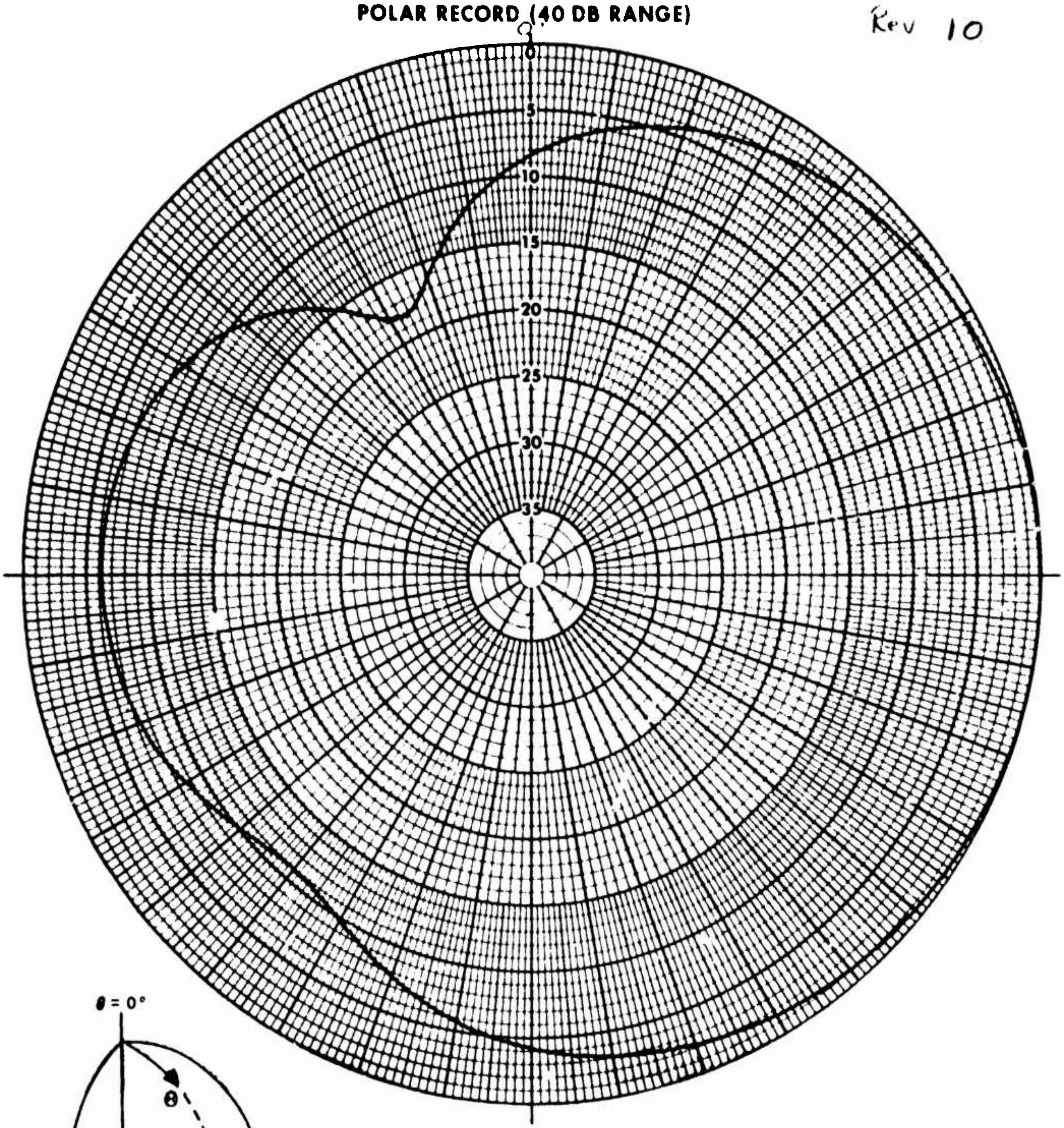
PROJECT 64941 DATE 6-14-73

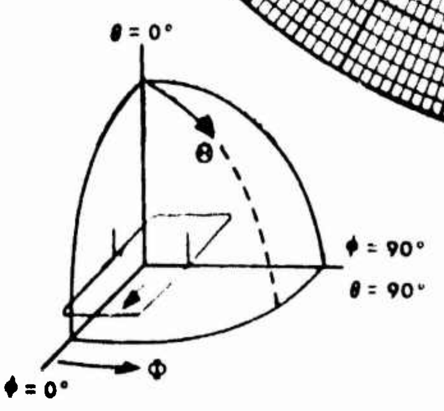
REMARKS AZIMUTH

75° DEPRESSION ANGLE

POLAR RECORD (40 DB RANGE)

Rev 10





POLARIZATION E_ϕ ____ , E_θ ✓

VARIABLE ANGLE Φ ✓ , Θ ____

CONSTANT ANGLE φ = ____ , θ = 15°

TECH ____ ENGR ____

THE **Magnavox** COMPANY

SHEET 10 OF 16

ANTENNA APR 3001C ARRAY

PROJECT 3371

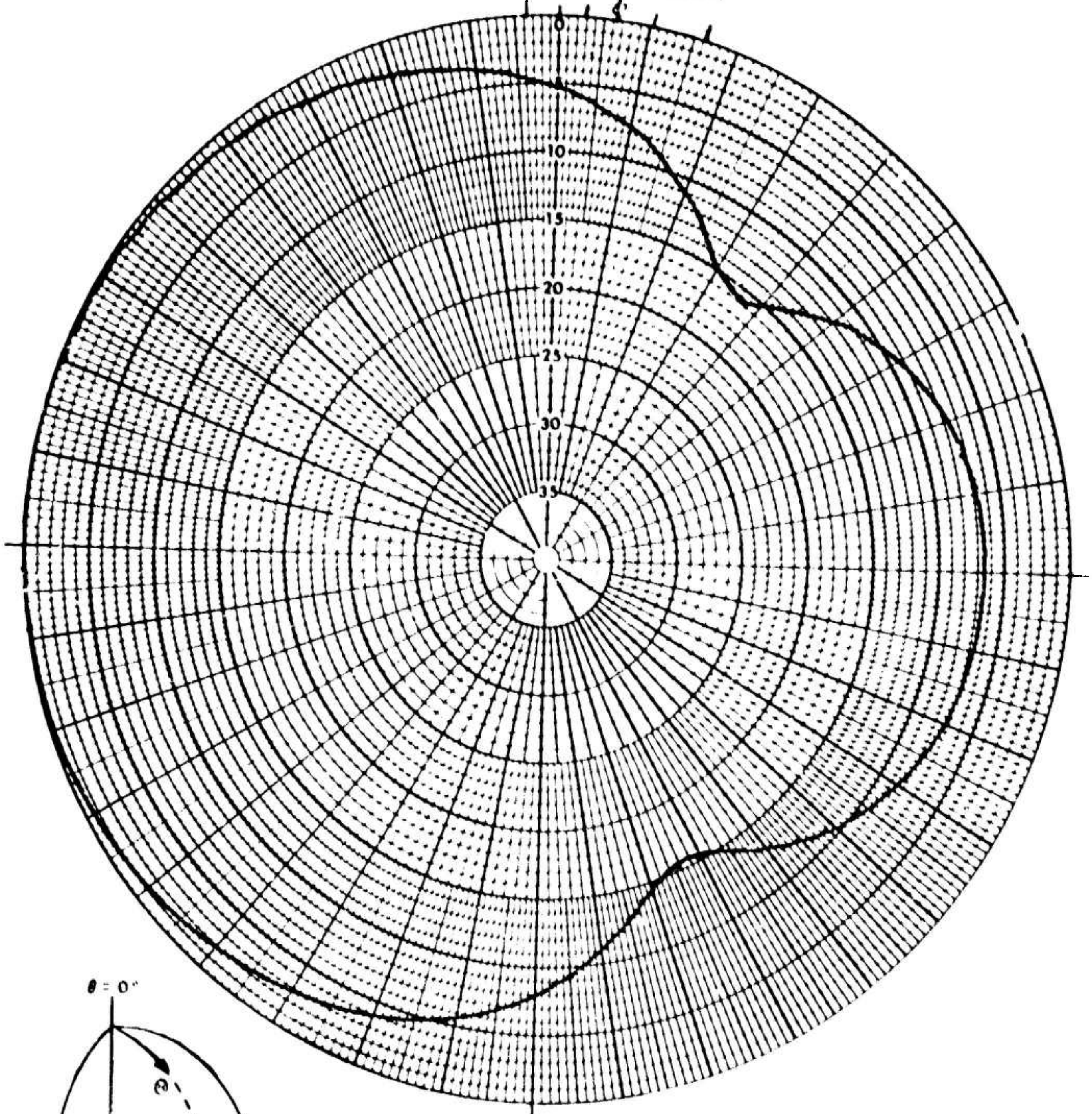
REMARKS DELMOUTH

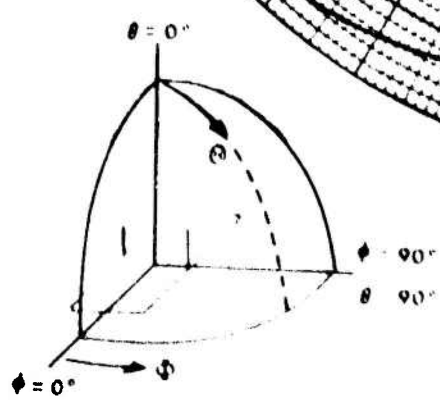
15° DEPRESSION ANGLE

SCALE FREQ MHz

DATE

POLAR RECORD (40 DB RANGE)





POLARIZATION E_{ϕ} E_{θ}

VARIABLE ANGLE Φ Θ

CONSTANT ANGLE φ θ 15°

TECH ENGR

THE **Magnavox** COMPANY

SHEET 11 OF 16

ANTENNA ADC 500/II ARRAY

SCALE FULL SCALE FREQ [illegible]

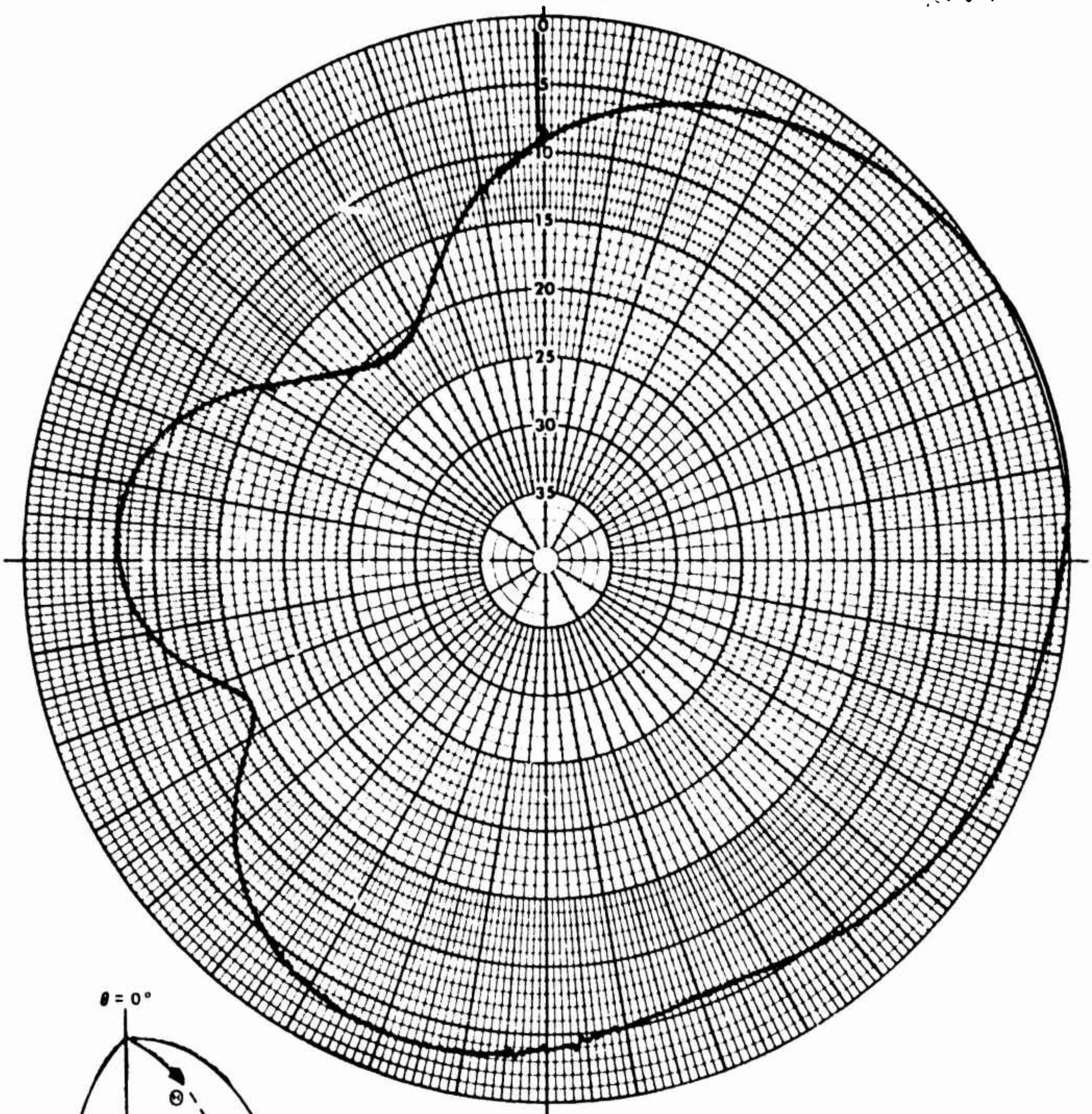
PROJECT 64941

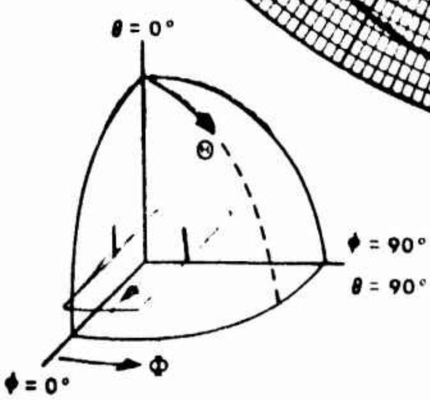
DATE 6-14-73

REMARKS ELEVATION - LEFT - RIGHT

POLAR RECORD (40 DB RANGE)

Rev 12





POLARIZATION E_ϕ ____ , E_θ ✓

VARIABLE ANGLE Φ ____ , Θ ✓

CONSTANT ANGLE ϕ = 90° , θ = ____

TECH ____ ENGR ____

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ANTENNA ADF 500/U ARRAY

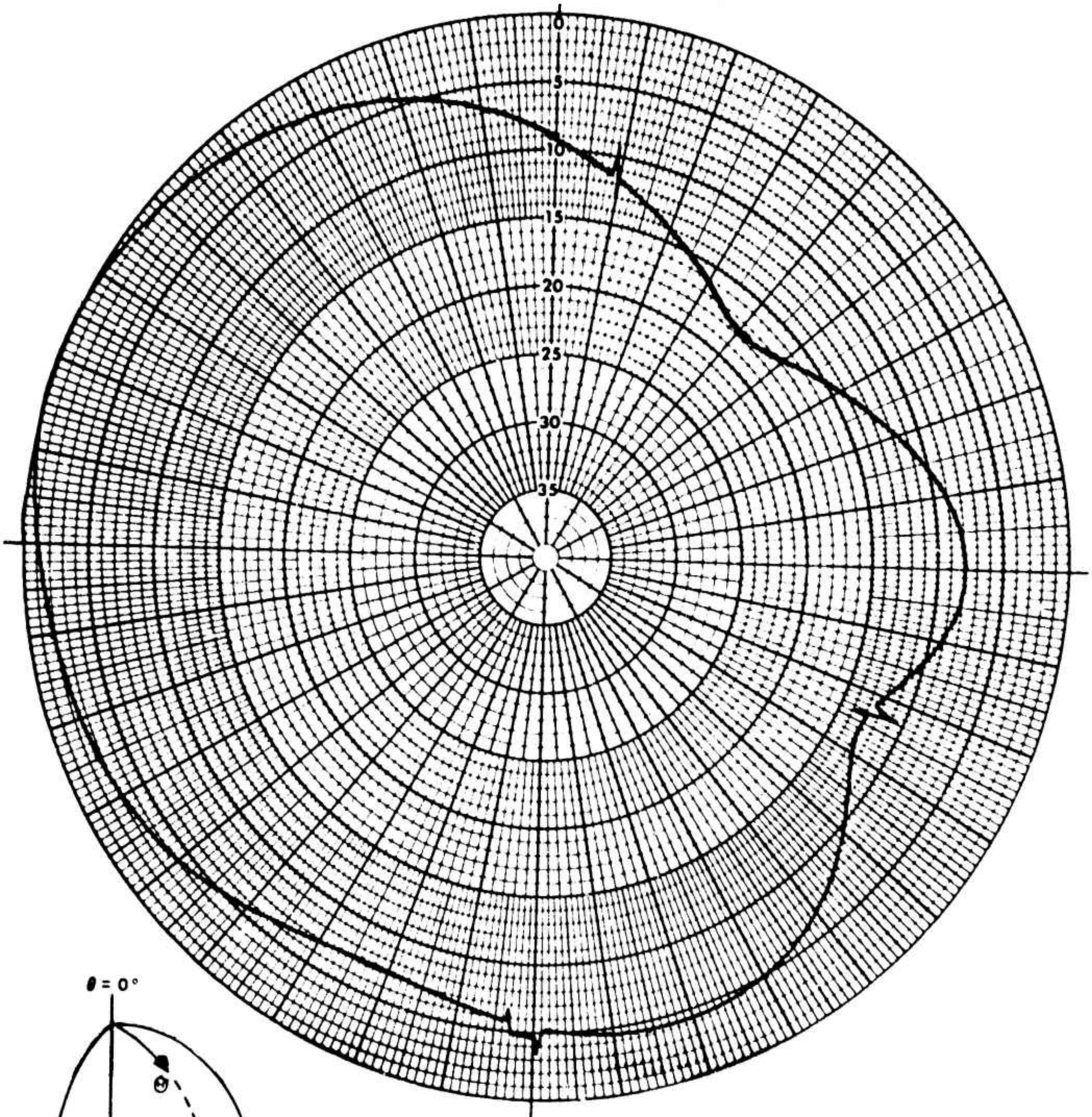
PROJECT 64741

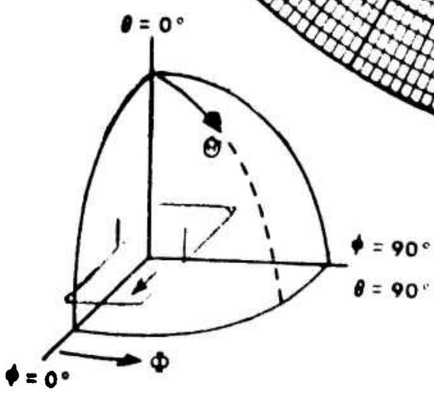
EMARKS ELEVATION - LEFT - RIGHT

SCALE FULL SCALE FREQ [illegible]

DATE [illegible]

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ . E_θ

VARIABLE ANGLE Φ . Θ

CONSTANT ANGLE φ = 90° . θ =

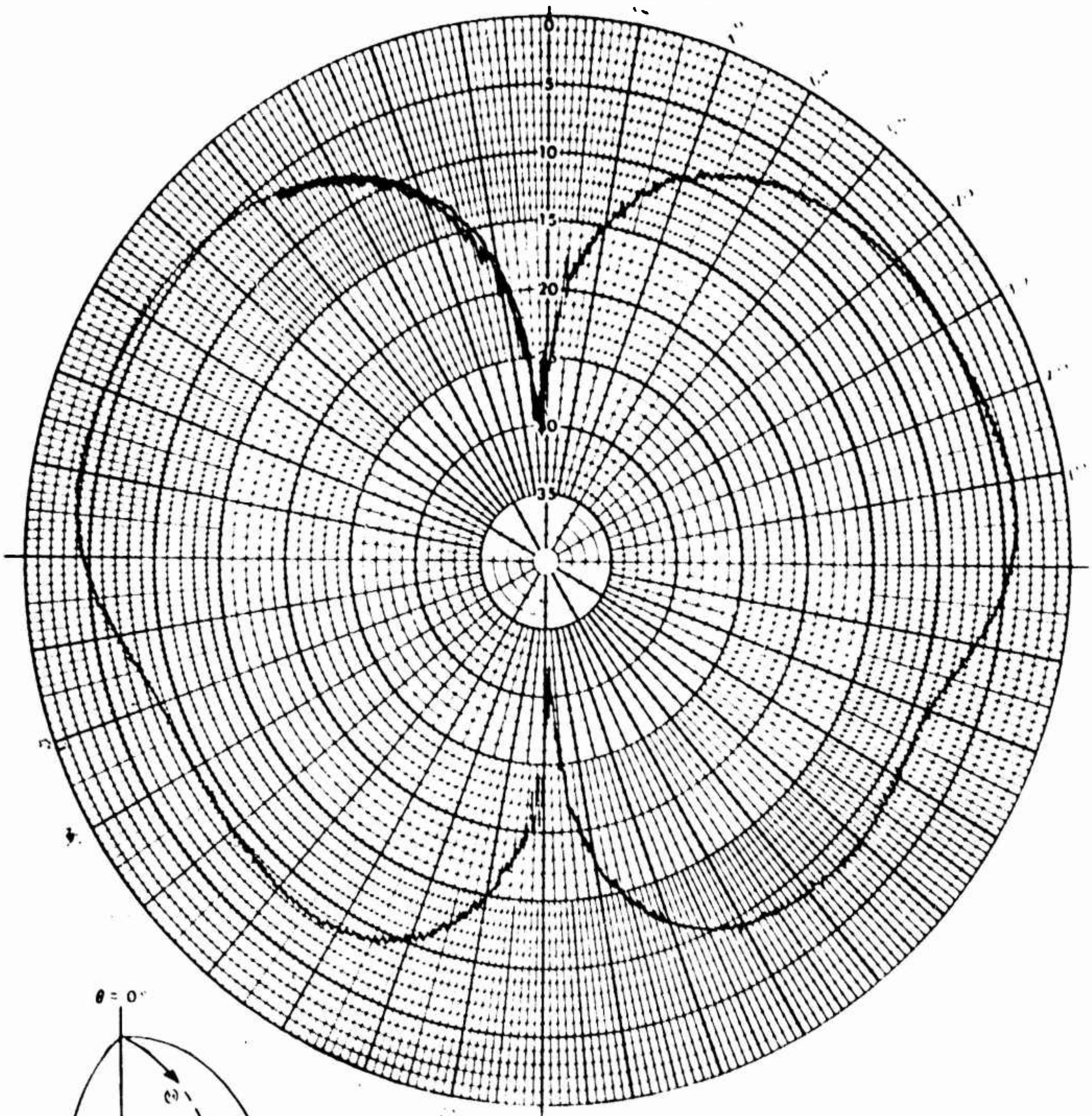
TECH . ENGR

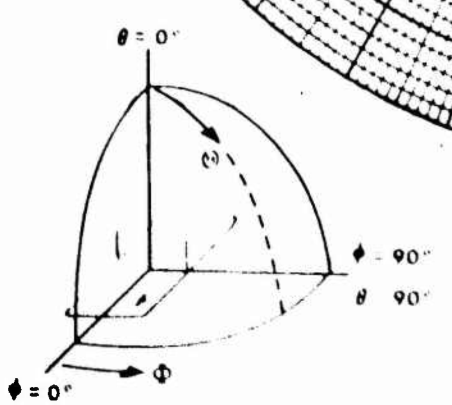
THE **Magnavox** COMPANY

SHEET 3 OF 62

ANTENNA [illegible] ARRAY	SCALE [illegible] SCALE FREQ [illegible]
PROJECT [illegible]	DATE [illegible]
REMARKS ELEVATION FORE - AFT	

POLAR RECORD (40 DB RANGE)





POLARIZATION E_ϕ	E_θ	
VARIABLE ANGLE Φ	Θ ✓	
CONSTANT ANGLE φ 0	θ	
TECH	ENGR [illegible]	

THE **Magnavox** COMPANY

SHEET 14 OF 16

ANTENNA ADR-500/U SINGLE ANTENNA

SCALE

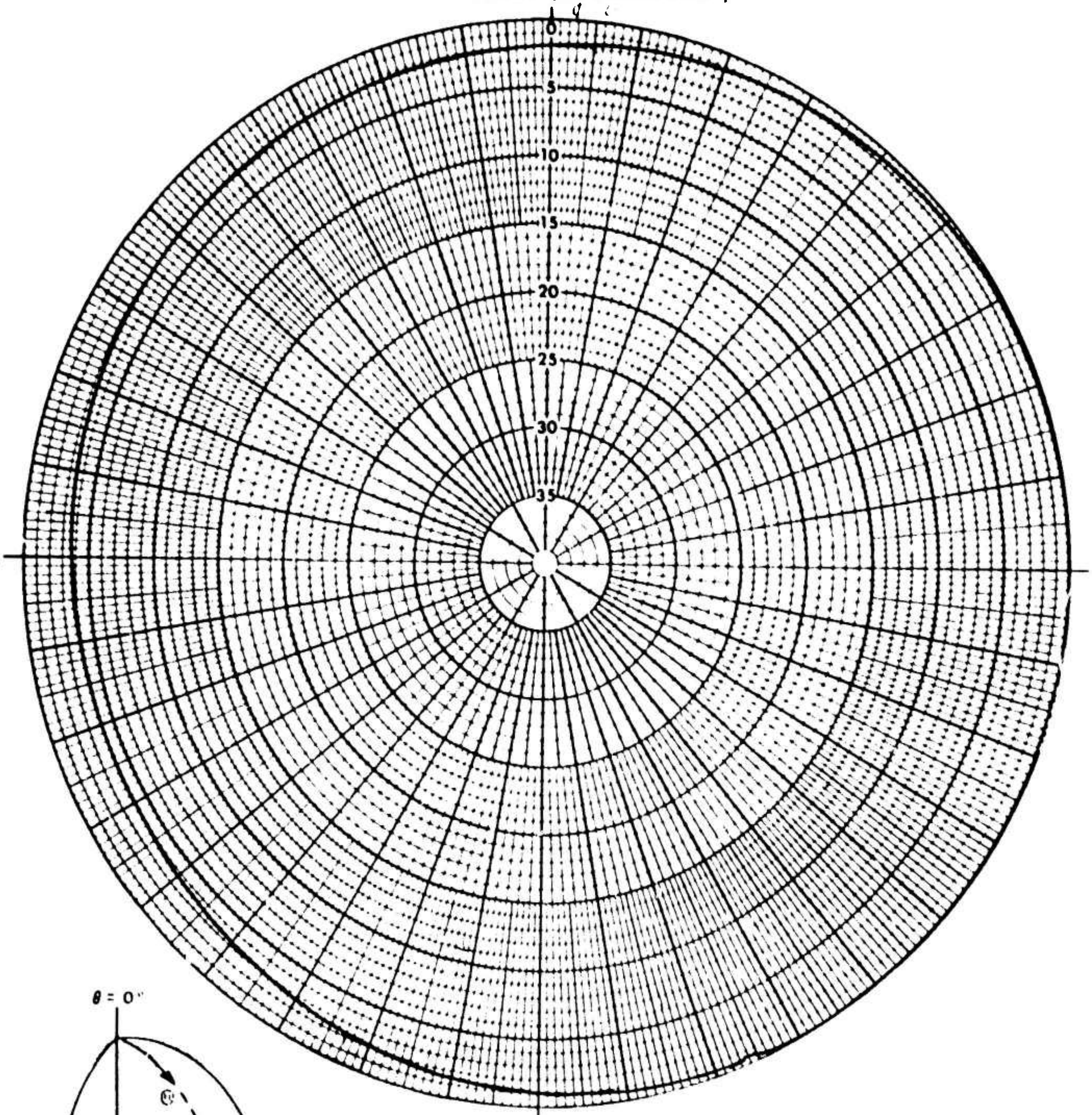
SCALE FREQ

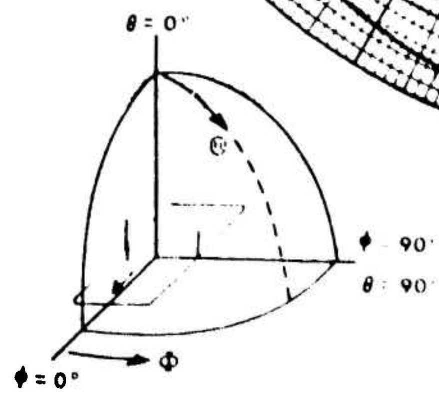
PROJECT 64941

DATE

MARKS AZIMUTH
0° DEPRESSION ANGLE

POLAR RECORD (~~VOLTAGE~~ 40DB PLOT)





V-15

POLARIZATION E_ϕ	E_θ ✓
VARIABLE ANGLE Φ ✓	Θ
CONSTANT ANGLE ϕ =	θ = 90°
TECH	ENGR

SHEET 15 OF 16

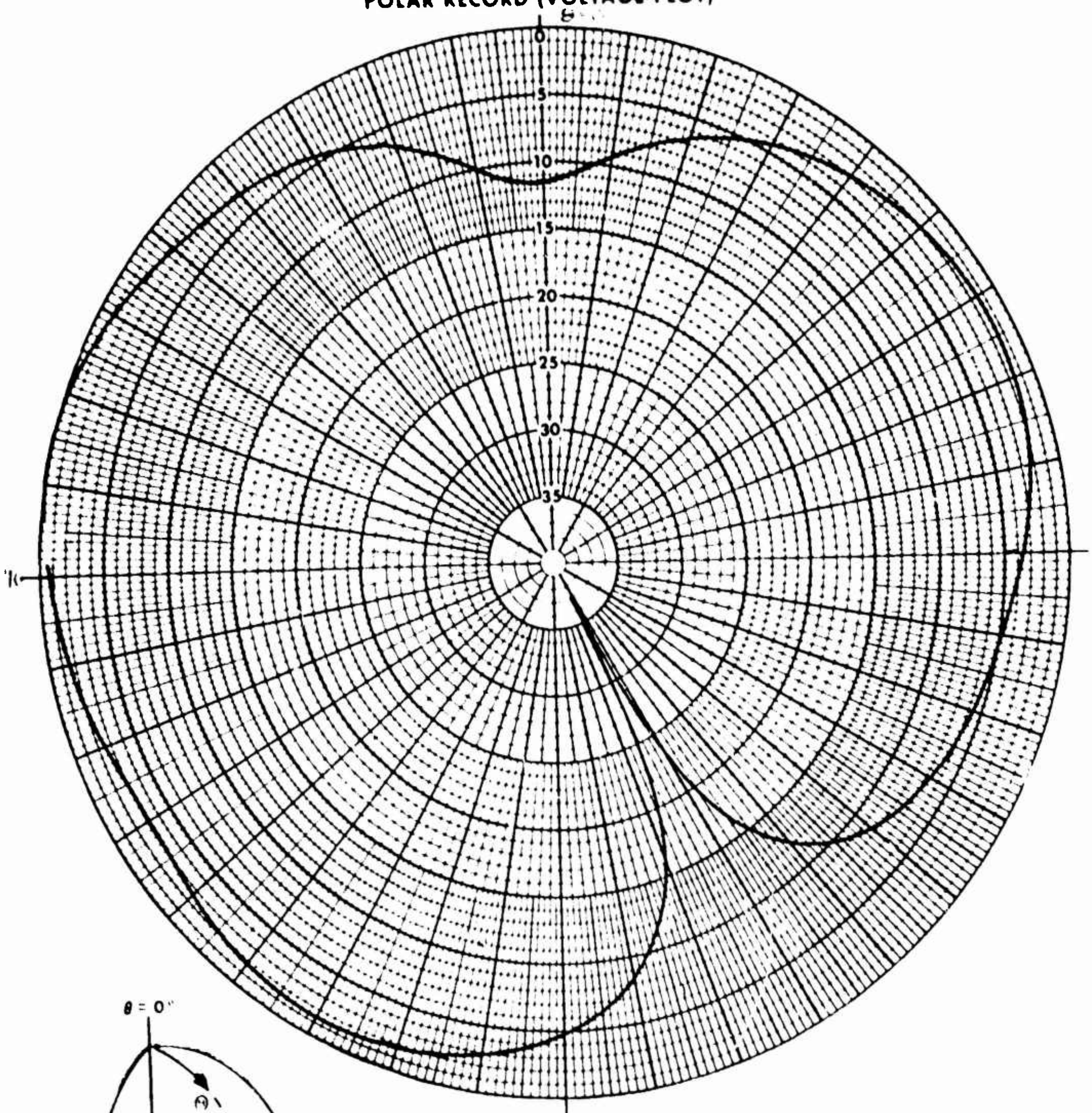
THE **Magnavox** COMPANY

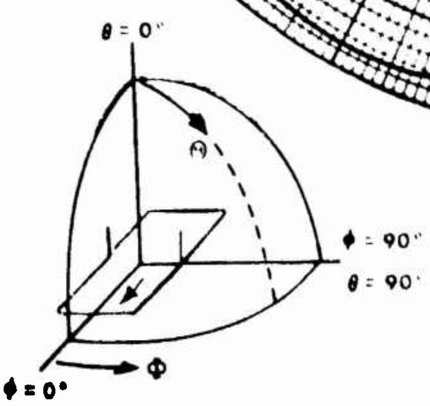
ANTENNA APX-500/U SINGLE ANTENNA SCALE ____ SCALE FREQ ____

PROJECT [illegible] DATE ____

REMARKS ELEVATION
LEFT-RIGHT

POLAR RECORD (~~VOLTAGE~~ 40DB PLOT)



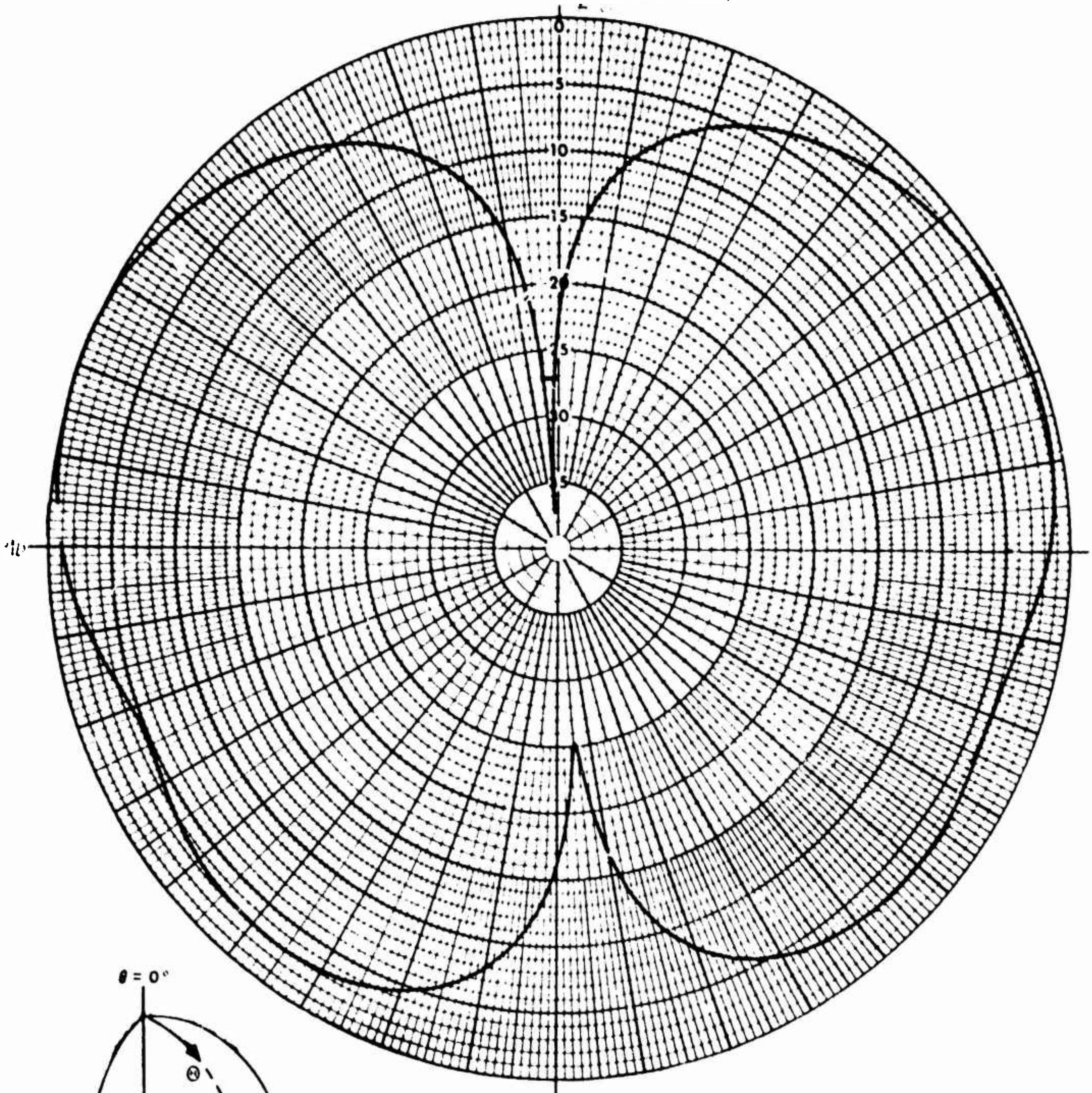


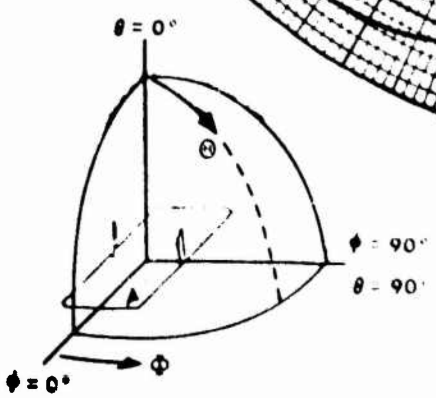
POLARIZATION E_ϕ		E_θ ✓	
VARIABLE ANGLE Φ		Θ ✓	
CONSTANT ANGLE ϕ =	90°	θ =	
TECH		ENGR	

THE **Magnavox** COMPANY SHEET 15 OF 16

ANTENNA	ADF-500/U ANGLE PATTERN	SCALE Full	SCALE FREQ
PROJECT	5594		DATE
REMARKS	ELEVATION FORE-AFT		

POLAR RECORD (~~VOLTAGE~~ 40 DB PLOT)





POLARIZATION E_ϕ	E_θ ✓	
VARIABLE ANGLE Φ	Θ ✓	
CONSTANT ANGLE φ = 0°	θ =	
TECH	ENGR	

APPENDIX B

- PRELIMINARY -
OPERATING INSTRUCTIONS
AGS-500
AIRDROP GUIDANCE SYSTEM

APPENDIX B

- PRELIMINARY -

OPERATING INSTRUCTIONS

AGS-500

AIRDROP GUIDANCE SYSTEM

Published: 14 October 1978

Prepared by: Approved by:

H. R. Reeder J. R. Hennel

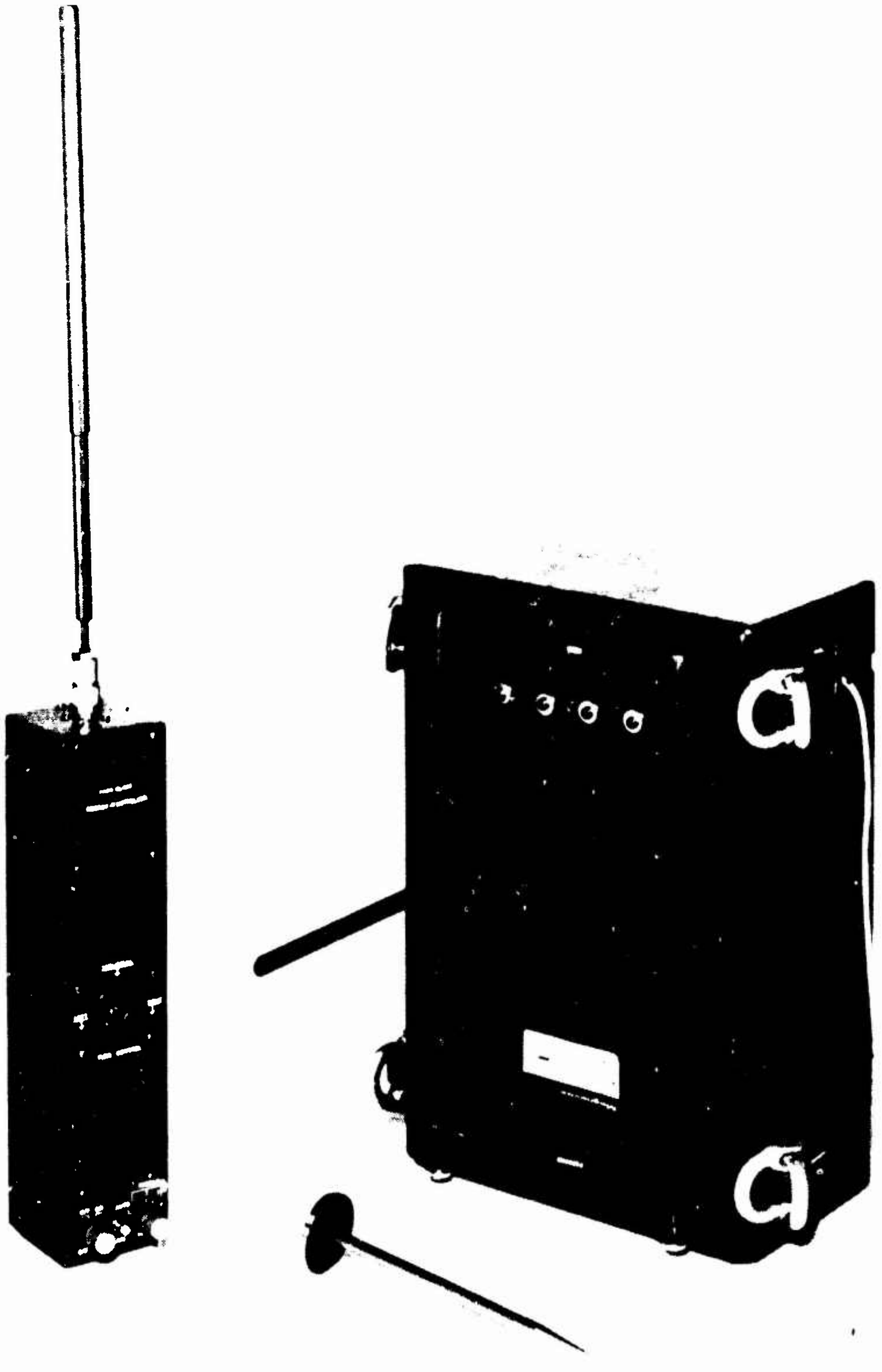
Magnavox

Government and Industrial Electronics Company

1313 PRODUCTION ROAD • FORT WAYNE, INDIANA

APPENDIX B

CONTENTS



AGS-500 Airdrop Guidance System

1.0 GENERAL

The AGS-500 Airdrop Guidance System has been developed to provide automatic guidance of cargo-carrying, flexible gliders to a selected impact point on the ground. The AGS-500 consists of two major electronic assemblies, the AGU-500, Airdrop Guidance Unit, and the BCT-360, Beacon/Control Transmitter.

1.1 AGU-500 Airdrop Guidance Unit

The AGU-500 Airdrop Guidance Unit is the airborne steering unit for the cargo carrying parachute. The AGU-500 has the primary function of mechanically manipulating the canopy steering lines so that the glider "homes" on a source of RF energy (the BCT-360) located on the ground. The AGU-500 is housed in a metal case measuring 16 inches long, 11 inches wide, and 8 inches high and weighing approximately 34 pounds. Two flexible tape antennae extend 8 inches from the bottom surface when the unit is in flight. The case is equipped with four mounting lugs each with two clevises which provide the suspension points between the parachute rigging and the cargo being delivered.

Major electronic subassemblies within the AGU-500 case consist of the mounting structure for the two direction-finding antennas, an antenna lobing switch, a radio receiver assembly, a control decoder assembly, a servo controller assembly, two servo motor drivers, and a steering cord motor drive assembly. Two rechargeable 12V batteries are included to provide primary power. These batteries are capable of providing 30 minutes to 2 hours of accumulated flight time before recharging-dependent upon battery temperature.

The AGU-500 will automatically home radially toward any source of RF energy which transmits at 360.4 MHz. The RF source on the ground may be voice modulated, tone modulated, or even noise modulated. When the BCT-360 is used as the ground homing beacon, the operator has the option to discontinue automatic radial homing and manually steer the cargo carrying subsystem to a location other than the transmitter site. Through the use of the BCT-360, the operator can also manually order the AGU-500 to execute a flare maneuver just prior to touchdown.

In situations that require multiple simultaneous drops, the operator can selectively address an individual subsystem for manual steering or flare while those subsystems not addressed continue to automatically home toward the BCT-360 transmitter output.

Two steering cords exit the rear of the AGU-500 for attachment to the canopy steering lines. Within the unit, the left and right steering cords are attached to left and right steering drums respectively. The steering drums are a part of the steering servos which retract the proper length of steering line when a turn is commanded. During maximum turn rates, approximately 24 inches of steering line is retracted at line

displacement rates up to 6 inches per second. During automatic homing, the length of steering line retracted during a turn is proportional to the angular error between the line-of-sight to the ground transmitter and the AGU-500 forward reference (dead ahead). The maximum steering line retraction (24 inches) occurs at angular errors of approximately 30 degrees and greater. Errors of 30 degrees or less provide proportionally smaller amounts of steering cord retraction.

During manual steering, steering line retraction is proportional to the position of the BCT-360 TURN CONTROL knob. The full 24 inches of retraction will occur when the TURN CONTROL is maximum CW or maximum CCW with zero retraction occurring when the TURN CONTROL is in its center or NEUTRAL position. Between the NEUTRAL and TURN CONTROL limits, steering cord retraction is directly proportional to the TURN CONTROL position.

When the BCT-360 is operating in the MANUAL MODE and the FLARE pushbutton is depressed, both the left and right steering lines are retracted the full 24 inches and remain in this position until the FLARE pushbutton is released.

The AGU-500 steering servos are capable of providing the specified performance with line tension up to 25 pounds. The steering line retraction servos are capable of exerting pull in excess of 75 pounds at reduced rates (92-pound theoretical stall torque), but loads of this magnitude will reduce servo useful lifetime below the expected 1000-hour minimum.

The AGU-500 has no operating controls other than a power on/off switch. This power switch is a spring-loaded pushbutton switch and is normally held in the off position by a force fit rubber plug. This rubber deployment plug is normally tied into the decelerator rigging in such a manner that it is automatically extracted from its socket by the opening deployment of the parachute, thus turning on the AGU-500 after the cargo has been ejected from the aircraft.

1.2 BCT-360 Beacon/Controller Transmitter

The BCT-360 Beacon/Controller transmitter is used at the anticipated landing site to provide the homing and control signals for the AGU-500 Airdrop Guidance Unit. The BCT-360 is housed in a metal case measuring 3 x 3 x 13 inches. The weight of the unit is approximately 5 pounds. The BCT-360 is provided with a removable dipole antenna assembly which measures approximately 17 inches in length and is 3/4 inches in diameter. Also included as an accessory is a removable ground support stake which may be thrust into the earth to support the BCT-360 when hand-held operation is not required.

Major electronic subassemblies within the AGU-500 case consist of a Control Encoder printed circuit card assembly and an RF Oscillator/Frequency Multiplier circuit card assembly. Two internal rechargeable

6V batteries provide primary power. These batteries are capable of providing from 8 to 20 hours operating time before recharging is required.

The BCT-360 transmits RF energy at a frequency of 360.4 MHz and at a power level of 0.4 watt minimum. The transmitter is continuously pulse code modulated by a repetitive 32-bit digital word used by the AGU-500 for Mode, manual steering, and flare control. The transmitted digital word also contains an address code which allows a specific AGU-500 to be addressed for manual control.

When oriented in a vertical position, the BCT-360 antenna radiates a horizontal "doughnut" pattern. Very little RF energy is radiated along the axis of the antenna.

The combination of BCT-360 transmitter power output and the AGU-500 receiver sensitivity is sufficient to ensure successful homing at slant ranges up to 15 miles (assuming the drop altitude is adequate to allow the airdrop unit to reach the target site).

Operating controls provided the operator of the BCT-360 are as follows:

a. Battery On/Off. - When placed in the ON position, turns on the RF transmitter and the digital encoder.

b. Mode Switch

(1) AUTO Position. - Causes the BCT-360 to transmit a reserved address code not matched to any AGU-500. Since this code is not recognizable by any AGU-500, all remain in the automatic (radial) homing mode.

(2) 1, 2, 3, 4 Positions. - Allows the operator to select specific parachutes for manual control. It is expected that the numbers 1, 2, 3, and 4 will correspond to the drop sequence used by the aircraft crew. (The prototype unit provides the same address code for all the numbered positions of the switch.)

c. FLARE Pushbutton. - When depressed, causes the AGU-500 to initiate flare maneuver. Functions only if the MODE switch is in a MANUAL 1, 2, 3, or 4 position.

d. TURN Control. - Provides manual steering of the AGU-500 unit selected by the MODE switch. Functions only if the MODE switch is in a MANUAL 1, 2, 3, or 4 position.

2.0 PREFLIGHT FUNCTIONAL TESTS

This brief functional test is to be performed prior to rigging the AGU-500 Airdrop Guidance unit to the decelerator and its cargo.

NOTE

The AGU-500 servos will be operated during this test. It is required that a small amount of tension be placed on each steering cord as the servos are operated both to evaluate the servo performance and to prevent possible steering line entanglement. The required line tension can be obtained either by grasping the ends of the cords manually or by adding small weights to the cord ends. Make certain that both steering lines are free to travel between the line marker and the AGU-500 case. (The line marker is a black thread sewn into the steering line approximately 27 inches from the AGU-500 case.)

a. Step 1. - Inspect the AGU-500 steering lines for wear or fraying which might cause breakage under flight stress. A stress test may be performed, if desired, by pulling the line straight out from the AGU-500 case until the line is restrained by the servo steering hub. Replace any steering line in poor condition using the instructions provided in the Steering Line Replacement section.

b. Step 2. - Make certain that the batteries of the AGU-500 and the BCT-360 have been charged in accordance with the instructions under Battery Care. Batteries which do not have a recent recharge history should not be used except under emergency conditions.

c. Step 3. - Inspect the AGU-500 flexible antennas for cracks or breakage. Replace any damaged antenna.

d. Step 4. - Attach the BCT-360 antenna to the BCT-360. (Note: Avoid turning the BCT-360 power on unless its antenna is in place. As with any transmitter, operating without an antenna load places unnecessary stress upon the output transistors.)

e. Step 5. - Place the BCT-360 controls in the following positions:

TURN CONTROL - Neutral
MODE SWITCH - MANUAL (1, 2, 3 or 4)
BATTERY - ON

The BCT-360 will now be transmitting a signal which will command the AGU-500 to the manual steering mode with the steering servos at approximately the neutral (straight ahead) position.

f. Step 6. - Place a small amount of tension to each of the AGU-500 steering lines so that each is stretched straight. Remove the rubber deployment plug from its socket in the AGU-500. The AGU-500 steering servos should run to the neutral position then stop. To check if the servos are at neutral, hold the steering lines perpendicular to the top surface of the AGU-500. A measurement with a tape measure should show that the travel markers sewn into the steering lines are 27 ±3 inches from the top surface of the AGU-500.

g. Step 7. - Rotate the BCT-360 TURN CONTROL slowly in the RIGHT (CW) direction. The right steering line should be retracted as the control is rotated. When the BCT-360 TURN CONTROL is maximum CW, the steering line marker should be within 3 to 8 inches of the top of the AGU-500 case.

h. Step 8. - Rotate the BCT-360 TURN CONTROL slowly in the CCW direction. The right steering cord should emerge from the case (assuming tension). When the TURN CONTROL is turned past neutral, the right steering cord must stop and the left steering cord should commence to retract. When the BCT-360 TURN CONTROL is maximum CCW, the left steering cord marker should be within 3 to 8 inches of the top of the AGU-500 case.

i. Step 9. - Return the BCT-360 TURN CONTROL to its neutral position. The left steering cord should emerge from the AGU-500 case.

j. Step 10. - Depress, and hold depressed, the BCT-360 FLARE pushbutton. Both steering cords should be retracted. A measurement should show that the cord travel markers are within 3 to 8 inches of the top surface of the AGU-500 case.

k. Step 11. - Release the BCT-360 FLARE pushbutton. Both steering cords should return to the lengths indicated by the TURN CONTROL position.

l. Step 12. - Place the BCT-360 MODE switch in the AUTO position. The AGU-500 servoes will probably re-position themselves to a new position which is generally unpredictable. The servos should respond to changes in position of the BCT-360 antenna. Place the BCT-360 antenna in several different positions within the room until it is established that both servos do respond to antenna position changes.

NOTE

Attempts to relate AGU-500 servo motion with the BCT-360 location in a closed area will be inconclusive due to reflections of the transmitter RF energy. If it is required that the direction-finding capability of the AGU-500 be tested, the test must be performed outdoors in an area free of objects capable of reflecting RF energy.

m. Step 13. - With the BCT-360 MODE switch in the AUTO position, check that the AGU-500 servos do not respond to changes in the position of the TURN CONTROL or the FLARE pushbutton.

n. Step 14. - Turn off the BCT-360.

o. Step 15. - Visually inspect the AGU-500 rubber deployment plug for cracks radiating from the groove. The retaining flanges of the rubber plug must be in good condition to prevent premature ejection of the plug and undesired power turn on. Replace the plug with a new plug if damage is present.

p. Step 16. - Lubricate the rubber deployment plug with silicon grease and reinsert it into the power switch receptacle to turn off the AGU-500 power.

3.0 GENERAL RIGGING REQUIREMENTS

Specific instructions for rigging the AGU-500 to the parachute and the cargo load will depend upon the specific application and is beyond the scope of this preliminary manual. However, the following general instructions shall apply.

While in flight, all parachute suspension and steering line risers should be terminated at the upper clevises on the AGU-500 mounting lugs. All right side parachute suspension lines should connect to the two right side clevises and all left side suspension lines should connect to the two left side clevises. The parachute suspension lines should maintain the AGU-500 package reasonably horizontal during straight flight.

The cargo being delivered is normally suspended beneath the AGU-500 by a harness fabricated from fabric webbing. The harness shall be constructed to equalize the weight of the cargo at attachment points on the AGU-500. The cargo suspension harness should be equipped with a

swivel so that cargo rotation is not transferred to the AGU-500 and subsequently to the parachute suspension lines. The length of the cargo suspension harness should separate the cargo three-to-five feet from the AGU-500 antennas.

When integrating the decelerator, the AGU-500 and the cargo into a droppable package, the following rules apply:

3.1 Steering Cord Connection

The decelerator steering lines must be adjusted to a length which provides straight and level flight and anchored to the upper clevises on the AGU-500 mounting lugs. This will cause opening shock forces to be transferred to the mounting lugs instead of the AGU-500 servos.

When the decelerator steering lines are positioned for normal straight and level flight, the AGU-500 steering lines are then attached to the parachute steering lines so that the travel markers will be positioned 26-1/2 inches from the top of their respective slots in the AGU-500 case. This will allow approximately 1/2-inch of slack in the AGU-500 steering line during straight and level flight commands. (A perfectly trimmed parachute will fly straight and level with no tension on the AGU-500 steering cords.)

As an example, if the AGU-500 steering lines are attached to the parachute steering lines at a straight line distance of 48 inches from the top of the slot in the AGU-500 case, the length of line between the attachment point and the travel marker will be 48 minus 26-1/2 or 21-1/2 inches. The actual length of the steering cord protruding from the AGU-500 may be meaningless since excess cord is stored on the servo drums and may be pulled out manually whenever the servos are not operating.

3.2 Antennae Stowage

When packing the AGU-500 to the cargo load, it is intended that the flexible antennae protruding from the bottom be folded inward parallel to the case bottom and maintained in this position by a layer of corrugated cardboard sandwiched between the AGU-500 and the cargo load. When the parachute and its cargo is dropped, the separation of the AGU-500 and the cargo must allow the cardboard to fall free to enable the antennae to spring erect.

3.3 Rubber Deployment Plug (Power Switch)

When packing the decelerator to the top of the AGU-500, a loop of line should be passed through the rubber deployment plug and tied to the parachute rigging in such a manner that the plug is pulled from its retainer by the opening of the decelerator. The rubber deployment plug should remain attached to the rigging so that it can be reused by personnel on the ground to deenergize the AGU-500.

4.0 GENERAL OPERATING PROCEDURES

4.1 Drop Zone Selection

If possible, select a drop zone which is clear of obstructions which may entangle the air dropped cargo. Avoid an area which contains nearby man-made objects; i.e., buildings, vehicles, etc., which may cause multiple reflections of the RF radiated by the BCT-360. (If a very strong reflection is present, the AGU-500 will "home" to a point somewhere between the BCT-360 and the source of the strong reflections).

4.2 Release Point Selection

The aircraft crew must release the bundle at an altitude and ground range relative to the landing site which assures that the bundle is capable of reaching the landing site. This release window generally takes the form of an ellipse the magnitude and position of which is calculated knowing the drop altitude, landing site altitude, decelerator forward and vertical velocities, and present wind velocity and direction relative to the landing site. If some of these factors are unknown, a release point at a depression angle of approximately 45 degrees directly upwind from the landing site will provide satisfactory results when the wind velocity does not exceed 75 percent of the forward velocity of the parachute.

4.3 Radial Homing

Select the desired landing site. Assemble the ground stake and the antenna to the BCT-360. Insert the ground stake into the earth to orient the BCT-360 antenna as nearly vertical as possible. Place the BCT-360 MODE switch in AUTO. Make certain that the BCT-360 BATTERY switch is in the ON position prior to cargo release from the aircraft.

When all cargo is down, turn off the BCT-360 transmitter. As soon as possible, retrieve the rubber deployment plug from the decelerator rigging and reinsert it into its receptacle on the AGU-500.

4.4 Radial Homing With Terminal Manual Steering

All drops will normally be initiated with the BCT-360 operating in the AUTO mode with manual steering being delayed until a visual observation indicates that the decelerator can be manually maneuvered to a more favorable position for the landing approach.

To initiate manual steering:

a. Place the TURN CONTROL to its NEUTRAL position.

b. Place the MODE switch to MANUAL (1, 2, 3, or 4 as required)

c. Rotate the TURN CONTROL to obtain the desired turn rate and direction.

d. The decelerator may be flared just prior to touchdown by depressing the FLARE pushbutton.

Automatic radial homing may be resumed at any time by placing the MODE switch to the AUTO position.

NOTE

> The AGU-500 requires approximately four seconds for the servos to run to the full flare position. The operator should be aware of this time delay when determining when to push the FLARE pushbutton.

4.5 Flaring Without Manual Steering

If manual steering is not required but it is desired to flare the decelerator just prior to touchdown, use the following procedure:

Preliminary. - Make certain that the TURN CONTROL is in the NEUTRAL position. (Generally, it is good practice to maintain the TURN CONTROL in the NEUTRAL position any time a bundle is in the air. This will assure a smooth takeover when either the manual steering or flare modes are activated.)

To flare prior to touch down:

a. Place the MODE switch to MANUAL (1, 2, 3, or 4 as required)

b. Depress and hold the FLARE pushbutton.

4.6 Hand-Held Operation

The BCT-360 may be operated when hand-held; however, the operator must be certain to orient the antenna properly. To provide maximum signal strength to the incoming AGU-500, the antenna must be maintained in a vertical position. The antenna pattern provided by the BCT-360 is "doughnut"-shaped with very little energy being radiated from the tip of the antenna. Pointing the tip of the antenna at the incoming parachute may cause loss of control due to reduced signal strength.

5.0 BATTERY CARE

The AGS-500 Airdrop Guidance System is powered by maintenance-free lead acid batteries. These batteries use a unique gelled electrolyte which allows them to be used when oriented in any position. With proper care,

the batteries provided can be expected to provide several years useful life under the light to moderate load requirements imposed by this homing guidance system.

The AGU-500 Airdrop Guidance Unit uses two Yuasa NP6-12, 12 volt, 6 ampere hour batteries for primary power. Fully charged batteries at a temperature of -40°C can be expected to properly power the AGU-500 Airdrop Guidance Unit for 30 minutes of normal flight time. At battery temperatures of 20°C, approximately two hours of operation can be expected before recharging is required. Since the steering motors are the major user of battery power, the operator must keep in mind that the actual battery life, prior to recharging, will be a function of the number of steering maneuvers required during an individual flight. Automatic radial homing at the longer ranges where steering requirements are moderate will extend useful battery life. Excessive manual steering, which requires the steering motors to run continuously, will reduce the time required before the batteries must be recharged.

The batteries selected for this application have adequate capacity to power the guidance unit for several successive flights without recharging. However, to assure successful completion of an airdrop or a series of airdrops, the batteries should be charged overnight prior to the first drop. The batteries should then be recharged if thirty minutes of flight time has been accumulated.

The BCT-360 Beacon/Controller Transmitter is powered with two Yuasa NP2.6-6M, 6 volt, 2.6 ampere hour batteries. When properly charged, these batteries will provide adequate power for eight hours of operation at -40°C and 20 hours of operation at +20°C. Although the useful life of these batteries, before recharging is required, exceeds the life of the AGU-500 batteries, successful airdrops are best assured if these batteries are recharged at the same time the AGU batteries are recharged.

5.1 General Rules for Battery Care

Never allow a battery to be stored for more than a few hours in a discharged condition. Prior to storage, each battery should be fully charged. These batteries will self discharge at the rate of two to three percent per month if stored at +20°C and 10 to 15 percent per month if stored at +95°C. Batteries in storage should be recharged at two to three-month intervals then returned to storage. If this procedure is followed, the batteries will be ready for immediate use if time is not available for recharging prior to an airdrop. Battery life is halved for each 20°F increase of temperature above normal room temperature, therefore, if possible, avoid storing batteries in excessively warm areas.

Protect the batteries from rough handling or blows which may crack the case. Even minute case cracks will allow the gelled electrolyte within the battery to dry out, thus rendering the battery useless.

When charging, never allow the battery charger output voltage to exceed +14.4 Vdc. Do not allow the charging current to exceed the following values:

NP6-12 (AGU-500) 0.9 amp
NP2.6-6 (BCT-360) 0.39 amp

The following general rules for charging the gelled electrolyte batteries are used for this system.

a. Initially charge each battery with the input current limited to the following "fast charge" rating of the specific battery:

   NP6-12 0.9 amp fast charge rate
   NP2.6-6 0.3 amp fast charge rate

   Monitor battery terminal voltage during this "fast charge" cycle. When the battery terminal voltage reaches 14.2 Vdc, the battery can be considered to be approximately 90 percent charged and charging at the "fast charge" rate must be discontinued to prevent overcharging. The battery may be placed in service at this time, if desired.

   If the battery continues to be charged at the "fast charge" rate after the battery terminal voltage exceeds 14.2V, an overcharge condition will result which will reduce the expected useful lifetime of the battery.

b. To "top off" the charge on a battery after it has been exposed to the "fast charge" cycle, reduce the charger voltage to 13.5 Vdc and leave the battery connected to the charger until it is ready to be placed in service. This 13.5 Vdc charger voltage is considered to be the "float" charge level. At this voltage, the battery will complete its charge, then will accept only the current necessary to maintain its full charge without danger of overcharging. Float charging can continue indefinitely without overcharging the battery.

WARNING

When connecting a battery to either a charger or the equipment it is required to operate, be very certain that the connections are properly made. Since these batteries have a high energy capacity, inadvertent reversal of battery connections can result in instant catastrophic destruction of any electronic equipment to which it is connected.

5.2 Battery Charging Procedure

Commercial battery chargers such as the Gates Model HL2-12 are available. These chargers are designed specifically for charging the gelled electrolyte batteries and incorporate automatic circuitry to switch from the "fast charge" mode to the "float" mode. Their use is recommended. General purpose DC power supplies may also be used if the charging rules specified in the preceding paragraph (5.1.4) are followed.

5.2.1 Charging AGU-500 Batteries

To gain access to the AGU-500 batteries, loosen the two large screws at the bottom edge of the battery compartment cover. Pull the lower edge of the battery compartment cover outward, then lift the cover off its upper retaining pins. Remove the two foam pads to expose the batteries. Disconnect both battery clips from each battery to isolate the batteries from the AGU-500 wiring.

The AGU-500 batteries may be charged separately or they may be connected in parallel and charged simultaneously. Always be certain to connect charger and batteries correctly (negative to negative and positive to positive).

5.2.2 Charging BCT-360 Batteries

To gain access to the BCT-360 batteries, remove the eight screws retaining the bottom cover. Remove the bottom cover to expose the batteries. Remove the battery clips marked CHARGER POSITIVE and CHARGER NEGATIVE. Leave the other two battery clips connected so that the batteries remain connected in series. (This series connection allows the two six volt batteries to be charged as if they were a single 12V battery.) Connect the charger positive connection to the battery terminal marked CHARGER POSITIVE and the charger negative terminal to the battery terminal marked CHARGER NEGATIVE.

When battery charging is complete, disconnect the charger, restore the wiring battery clips to their respective battery terminals, then reassemble the hardware.

6.0 STEERING LINE REPLACEMENT

Prior to each flight, the AGU-500 steering lines should be visually inspected for wear and any steering lines not in satisfactory conditions should be replaced. To replace worn steering lines, use the following procedure:

CAUTION

The steering drums are mechanically restrained from turning more than two and a half turns each side of the neutral position by fragile

mechanical stops provided by the servo followup potentiometers. To avoid damage to the potentiometers, do not exceed the number of turns specified in the following procedure when turning the steering drums by hand.

6.1 Preliminary

a. Step 1. - Place the AGU-500 on a bench so that the rear of the AGU-500 is oriented toward the operator.

b. Step 2. - Remove the four screws retaining the top cover and remove the top cover.

6.2 Steering Line Removal

The following removal procedure applies to both left and right steering lines.

a. Step 1. - While observing the steering drum, grasp the steering line and pull outward slowly until the large hole in the drum which contains the line knot is visible and accessible.

b. Step 2. - With a pair of long nose pliers, grasp the knotted end of the steering line and pull the cord out of the drum hole. Remove the worn line completely and discard.

c. Step 3. - Repeat steps 1 and 2 in subsection 6.2 for the other steering line.

6.3 Setting Servos to Neutral

a. Step 1. - Turn on the BCT-360. Place the MODE switch to "1" (MANUAL). Center the STEERING control to NEUTRAL.

b. Step 2. - Momentarily remove the rubber deployment plug to turn on the power to the AGU-500. The steering servos should rotate to approximately their neutral position. If desired, the BCT-360 STEERING control can be fine adjusted until the punch marks on the AGU-500 steering drums are aligned with the punch marks on the drum housing. Re-insert the rubber deployment plug to turn off the AGU-500 power. The steering drums are now centered near their neutral position.

c. Step 3. - Turn off the BCT-360.

6.4 Left Steering Line Replacement

a. Step 1. - Manually rotate the left steering drum approximately 1-1/2 turns clockwise until the large hole in the drum is accessible from the top.

b. Step 2. - Cut a new steering line approximately six feet long. Tie a retaining knot (stevedores knot or similar) on one end.

c. Step 3. - Insert the unknotted end of the new steering line into the large hole pushing it clear through the drum. Continue to push the line through the drum until approximately 12 to 20 inches of line has been pushed through.

d. Step 4. - Manually rotate the steering drum counterclockwise until the unknotted side of the new steering line is accessible where it exits the steering drum. Grasp the unknotted side of the new steering line and pull the line through the steering drum until the knot is firmly seated in the drum.

e. Step 5. - Thread the end of the steering line downward along the left edge of the steering drum, under the left nylon idler pulley and out the case slot.

6.5 Right Steering Line Replacement

a. Step 1. - Manually rotate the right steering drum approximately 1-1/2 turns counterclockwise until the large hole in the drum is accessible from the top.

b. Step 2. - Cut a new steering line approximately six feet long. Tie a retaining knot (stevedores or similar) on one end.

c. Step 3. - Insert the unknotted end of the new steering line into the large hole pushing it clear through the drum. Continue to push the line through the drum until approximately 12 to 20 inches of line has been pushed through.

d. Step 4. - Manually rotate the right steering drum clockwise until the unknotted side of the new steering line is accessible where it exits the drum. Grasp the unknotted side of the new steering line and pull the line through the steering drum until the knot is firmly seated in the drum.

e. Step 5. - Thread the end of the steering line downward along the right edge of the steering drum, under the right nylon idler and out the case slot.

6.6 Line Installation Check

Momentarily remove the rubber deployment plug to apply power. After the servo motors stop running re-insert the deployment plug to turn off the unit. The motors should have stopped with the servos positioned near their neutral position. If the steering lines have been

installed correctly, each drum should contain approximately 3/4 turn of steering cord when the servos are positioned at neutral. When all slack line is pulled outside the unit, each line path should be from the drum, under the idler roller then out the case slot.

6.7 Installation of Travel Marker

a. Step 1. - Manually rotate each steering drum to line up the drum punch mark with the drum housing punch mark. Make certain that the drums are at the neutral position by determining that 3/4 turn of cord is present on the drum.

b. Step 2. - Without rotating the steering drums, pull all slack out of each steering line and hold the line straight up so that it is perpendicular to the top surface of the case. Using a ruler, permanently mark each steering line at a distance of 27 inches from the top surface of the case. (A black thread is sewn into the steering lines as travel markers in the prototype unit.)

CAUTION

When the steering lines are rigged to the decelerator, the line between the travel markers and the case of the AGU-500 must be kept free of connectors, knots, etc. When connecting the AGU-500 steering lines to the decelerator steering lines, it must be kept in mind that both travel markers will be 27" from the top of the AGU-500 case when the system is in a straight and level flight.

7.0 THEORY OF OPERATION

7.1 BCT-360 Beacon Controller Transmitter

When operating, the BCT-360 continuously transmits a 16-bit data word on a 360 MHz RF carrier. The transmitted digital data contains the control information to (1) select a particular cargo carrying canopy for manual control, (2) manually steer the selected canopy and (3) to manually flare the selected canopy. A block diagram of the BCT-360 is shown in figure B-1.

The RF section consists of transistors Q1 through Q6. Transistor Q1 is a crystal-controlled oscillator which provides the stable 90.1 MHz reference frequency. The oscillator frequency is buffered by buffer Q2, then doubled twice by doubler stages Q3 and Q4 to obtain the desired 360.4 MHz output frequency. Transistors Q5 and Q6 provide the power gain required to obtain the required 400 mW of RF power at the antenna input. Pulse modulation of the RF output is provided by keying on and off the second frequency doubler stage, Q4, using the digital data signal provided by the control data encoder.

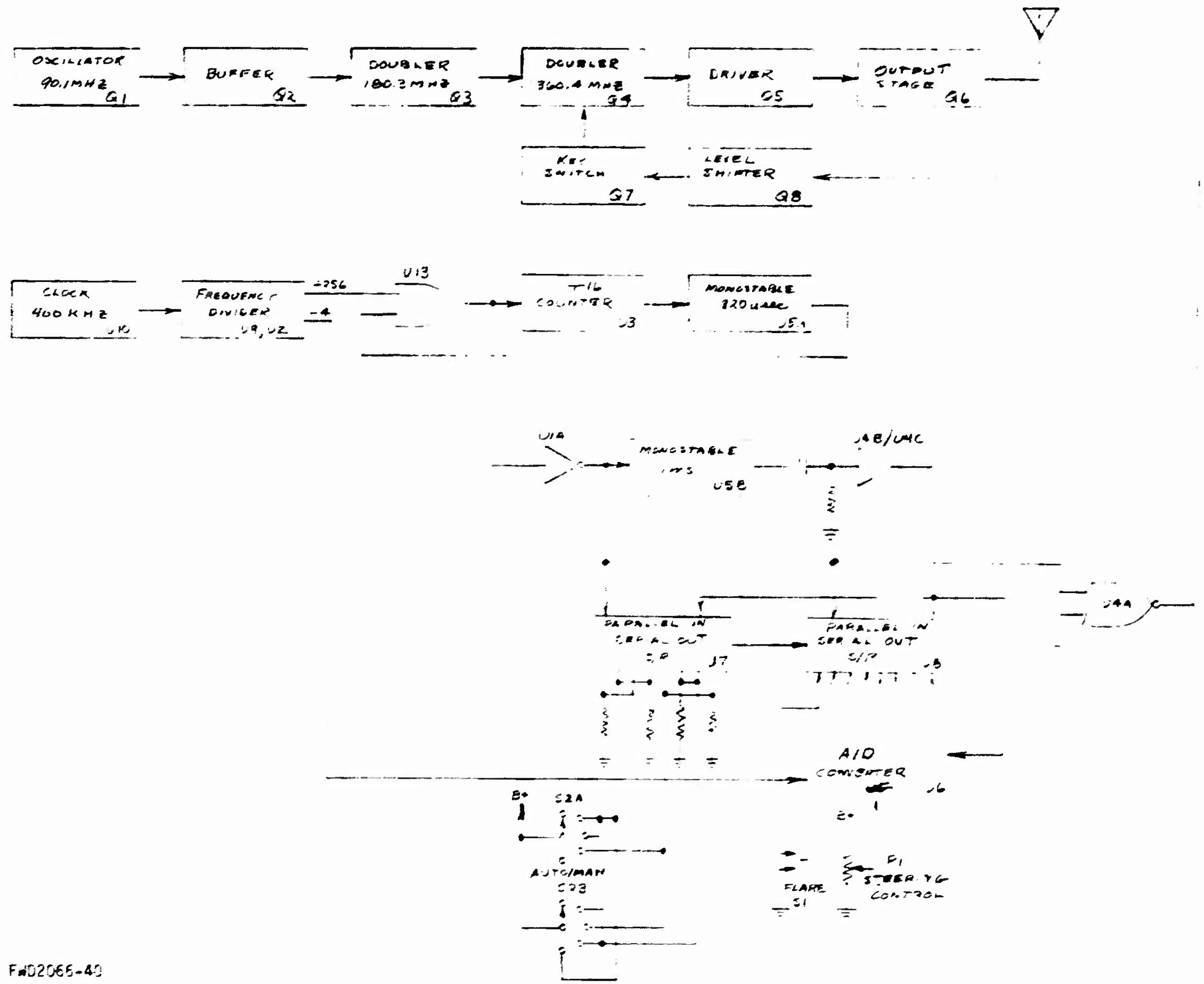


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Figure B-1. BCT-360 Beacon/
Controller Block Diagram

The control data encoder consists of the controls, S1, S2, and R1; the steering control A to D converter U6; a 16-bit shift register, U7 and U8; a word synchronizer consisting of U1B, U3, and U5; and a clock pulse generator, U2, U9, and U10.

The encoder clock is provided by U10 which is stabilized at 400 kHz by a ceramic filter operated in the parallel resonance mode. This 400 kHz clock frequency is divided down to 100 kHz and 1.5 kHz by the frequency divider consisting of U2 and U9. The 100 kHz clock is used to clock the A/D converter, U6. The 1.56 kHz clock is used as the clock for the parallel data-to-serial data converter and establishes the bit rate for the transmitted data word.

The control data word is 16 bits in length followed by a 1 bit dead time and is transmitted continuously. Data bits 1 through 7 of the data word are used to transmit steering commands. Bit 8 is used to transmit the flare order and data bits 9 through 16 are used to address a particular canopy for manual control. All control data is entered into the shift registers as parallel data then clocked out of the shift register as serial data to form the transmitted serial data word.

The canopy address code is provided by switch S2 and the flare command is provided by switch S1. Manual steering data is provided by the Analog-to-Digital converter, U6, which converts the analog DC voltage from R1 to the required binary digital format.

Integrated circuits U1B, U3, and U5A are used to control the word length at 16 bits followed by the 1 bit dead time. The 1.56 kHz clock is inverted by U1B, then counted by U3. When the clock pulse count reaches 16, the output of U3 triggers the monostable multivibrator, U5A. The period of U5A is such that, when it is triggered, one clock pulse is gated out by U1B. The signal at U1B output will then be 16 clock pulses followed by a missing clock pulse. This clock signal is also used to step the serial data out of the shift registers, U7 and U8.

The serial data and the clock signal are manchester-encoded by the exclusive OR, U4A. The output of U4A is either the clock signal inverted when the serial data is at the logic 0 level or it is the clock signal not inverted when the serial data is at the logic 1 level.

Multivibrator U5B is a retriggerable multivibrator with a period slightly longer than the period between clock pulses. U5B is triggered by the first clock pulse and remains triggered as long as consecutive clock pulses are present. The time interval occupied by the missing clock pulse is long enough to allow U5B to return to its normal state and, when this occurs, a short pulse is created which is used to jam the parallel data into the shift register.

7.2 Airborne Canopy Guidance Unit

7.2.1 General

A simplified block diagram showing the major components is found in figure B-2.

The radio frequency signals received by both antennas are phased by means of the Antenna Lobing gate to produce a cardiod pattern either to the right or to the left depending upon the polarity of the 65 Hz gate generated in the Servo Controller module. This switching of the antenna pattern right and left produces an RF output to the receiver which has the required directional sense for radial homing. As an example, if the RF source is to the right of center, the RF signal will be greatest when the cardiod antenna pattern is switched to the right and reduced in amplitude when the cardiod pattern is switched to the left.

The resulting modulated RF signal is amplified and detected in the UHF Receiver Module. The detected audio output of the receiver contains the 65 Hz modulation superimposed upon any amplitude modulation which may be present on the RF signal being received by the antenna.

The control decoder processes the audio and produces the correct steering analog signal to the Servo Controller Module. Circuits within the Control Decoder monitor the receiver audio output and, if the signature transmitted by a BCT-360 is not recognized, the steering signal output will be the radial homing steering signal. If the receiver audio contains the BCT-360 signature code and if the code matches the internal hard wired code, the steering signal output will be that derived from the BCT-360 manual steering control. If a code match is found and the incoming data word contains the FLARE order, the steering control signals produced will be those required to run the steering servos to the flare position.

The Servo Controller module contains the summing amplifiers required to program the left and right steering so that each servo follows the commands of the steering signal inputs from the Control Decoder.

7.2.2 Control Decoder

The Control Decoder (see figure B-3) assembly is used to convert the receiver output signal to a DC analog signal which is proportional to the homing deviation angle. Also, when the received signal originates from a BCT-360, this assembly decodes the BCT-360 serial data word to provide the manual steering analog, flare analog, and control logic signals.

7.2.2.1 AGC Boost. - The AGC Boost circuit is used to provide additional AGC to the receiver to prevent audio clipping under very strong signal conditions. The receiver detector output (DC + Audio) is connected through connector pin N to a voltage comparator, U20. If the receiver

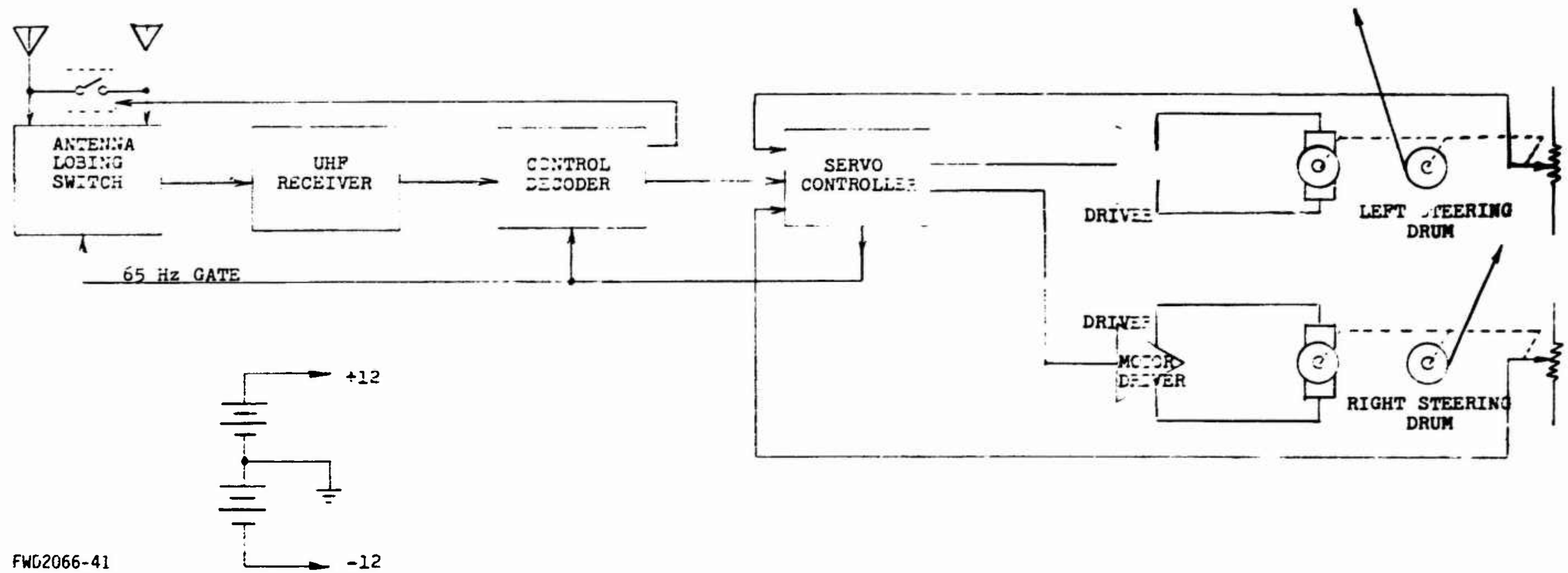

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Figure B-2. Simplified Block Diagram
Airborne Canopy Guidance Unit

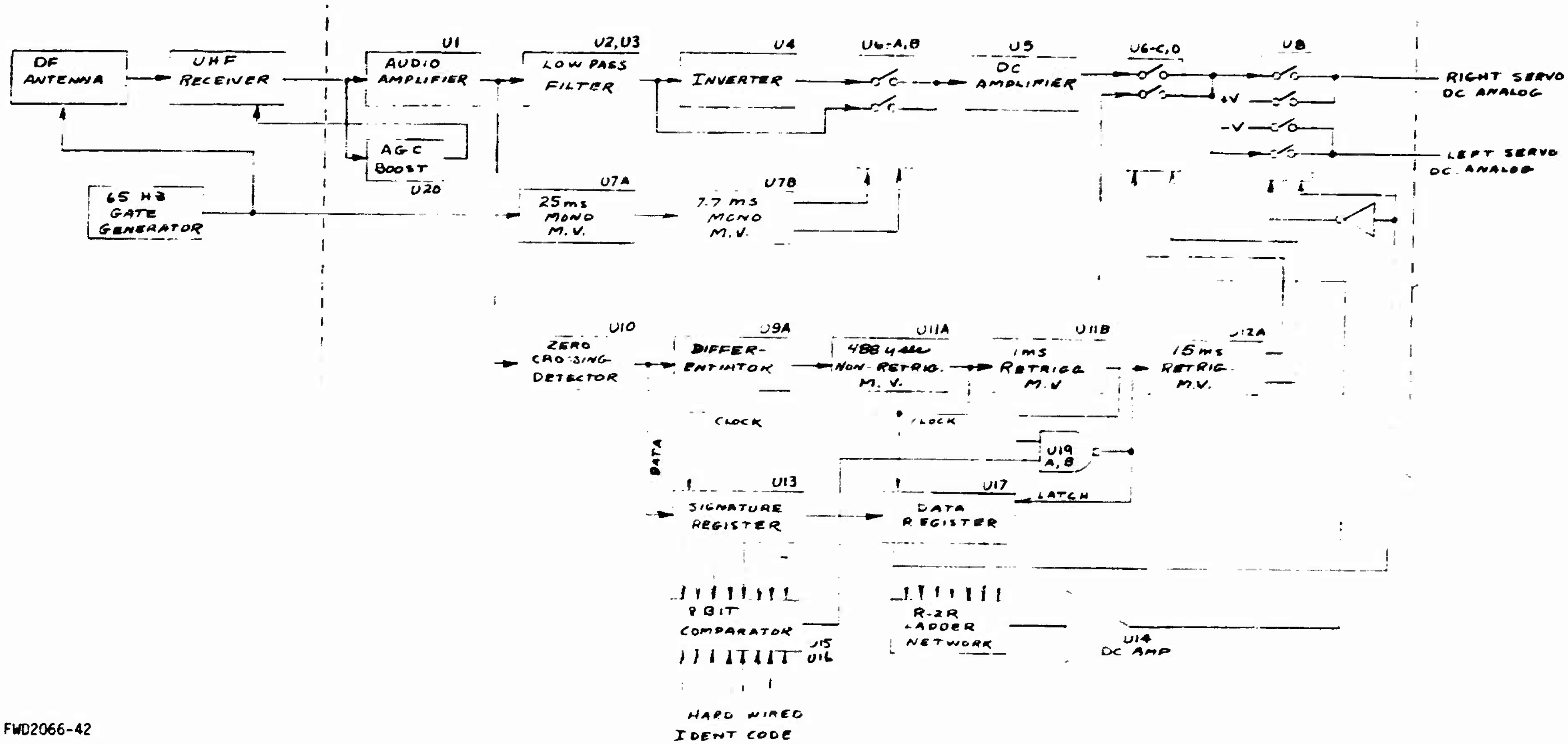

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Figure B-3. Detailed Block Diagram, Control Decoder Module

output level exceeds +1.16 Vdc, the comparator output, pin 7, switches from +6 Vdc to -6 Vdc. This negative signal is used to provide additional negative bias to the normal receiver AGC buss.

7.2.2.2 Audio Amplifier. - The AC component of the receiver output is coupled through a capacitor to U1 where it is amplified times 10.

7.2.2.3 Radial Homing Steering. - The signal chain used to develop the steering signal during radial homing consists of a low pass filter, a synchronous detector, and a DC amplifier. The amplified receiver audio is passed through a low pass filter consisting of two 12 dB/octave active stages, U2 and U3. The corner frequency of these filters is at 89 Hz which effectively removes all audio except the 65 Hz modulation caused by homing heading errors. This 65 Hz signal is inverted without amplification by the inverter, U4. The 65 Hz error signal and its complement are then used as the input to the synchronous detector consisting of the dual transmission gate and monostable multivibrator U7B.

Monostable multivibrator U7A is triggered by the leading edge of the antenna lobing gate generator and is used only to provide a fixed delay equivalent to the phase shift of the 65 Hz signal introduced by the low pass filters, U2 and U3. The trailing edge of the output of U7A is used to trigger the multivibrator U7B which produces an output pulse (and its complement) the width of which is equal to one-half the period of the incoming 65 Hz error signal. The Q and $\overline{Q}$ outputs of U5B alternately open and close the transmission gates to provide the synchronous detection of the 65 Hz error signal. The resulting DC output from the transmission gate is amplified and filtered by the DC amplifier U5. If the manual mode of operation has not been selected, this DC error signal is passed through the transmission gate U6C to provide the steering signal to the steering controller module.

7.2.2.4 Manual Mode Steering Signal. - When the BCT-360 is used as the homing transmitter, the audio out of U1 will be the 16-bit manchester-encoded data word. This audio is used as the input to the comparator, U10 which functions as a zero crossing detector to restore the audio to fixed amplitude digital square waves. This recovered digital data word is used as the data input to the 16 bit serial in parallel out shift register consisting of U13 and U17. This same signal is also used as the input to the clock recovery circuit consisting of U9A and U11A.

As stated previously, manchester encoding of a digital data word consists of either inverting or not inverting a clock signal depending upon whether the data is a logic 0 or a logic 1. The encoded signal will therefore consist of pulses which are either one-half a clock period wide or a full clock period wide depending upon whether an individual data bit is the same as or different from the previous data bit. To recover the original clock signal all that is necessary is to create a short pulse for every transition of the encoded data word and use these pulses to trigger a non-retriggerable multivibrator whose natural period is equal to approximately three quarters of the actual clock period (480 μsec).

Since the period of the multivibrator is too long to be retriggered by pulses which are a half a clock period in length (320 μsec), the multivibrator will automatically synchronize its output to the first data pulse which is a full clock period in length and will remain in synchronization thereafter. The trailing edge of the multivibrator output is used to clock the data from the zero crossing detector into the shift register.

Since the trailing edge of the multivibrator is positioned at approximately three quarters of a clock period, the logic level clocked into the shift register will be either a logic 0 for an inverted clock pulse or a logic 1 for a non-inverted clock pulse.

As previously stated, the data word transmitted by the BCT-360 is a sixteen-bit data word followed by a missing clock pulse. The position of the missing clock pulse is used as an "end-of-word" marker and this end-of-word marker is detected by the retriggerable monostable multivibrator, U11B. The shift register clock generated by U11A is also used to trigger U11B. The natural period of U11B is set to approximately 1 millisecond which is longer than the 640 μsec clock period. The first clock pulse generated by U11A will trigger U11B and U11B will remain triggered as long as U11A continues to produce pulses spaced at 640 μsec. Since no clock pulse is produced at the end-of-word time, U11B is allowed to time out and produce a pulse.

As previously stated, the BCT-360 transmits an address code used to address a particular canopy. This address code is recovered from the serial data word by the shift register, U13. The eight bits of the address code are then compared with a hard wired code by an eight-bit comparator consisting of U15 and U16. If the comparator finds a code match, a logic 1 will appear at its output.

Shift register U13 is wired so that the latch function is not used, therefore, incoming serial data is continuously passed through to its parallel outputs. Consequently, the only time the comparator will produce an output indicating code agreement is when each of the 16 bits of the incoming serial data word is properly positioned in its proper register. If the address match pulse and the end-of-word pulse occur simultaneously, the AND gate, U19A, will produce a pulse which updates the steering data at the outputs of U17 and also triggers the retriggerable monostable multivibrator U12A.

Monostable M.V., U12A, is connected as a missing pulse detector with a natural period which is slightly greater than the period required for one complete serial word. As long as the BCT-360 continuously transmits the proper address code U12A will remain in the triggered condition. The output of U12A is then used to switch the canopy guidance system from the radial homing steering analog signal to the manual steering analog signal.

The digitally encoded manual steering signal is provided by the first seven bits of the BCT-360 serial data word. These seven bits are outputted from the parallel outputs of the shift register U17 and returned to a DC analog by means of an R-2R resistive ladder network. The analog output from the R-2R loader is scaled by a DC amplifier, U14.

When manual steering is selected, the manual steering analog signal is connected through the transmission gate, U6D, then through the transmission gate, U8, for use by the servo controller module.

The transmission gates of U8 are used to switch from the steering signals to the fixed DC flare signals which cause the servos to slew to the maximum deflection position. The flare mode is initiated by the appearance of a logic 1 at the flare output position of the shift register U13.

7.2.3 Servo Controller

A block diagram of the Servo Controller module is shown in figure B-4. This module uses the steering control signals provided by the Control Decoder module and converts them to drive signals capable of pulse width modulation of the motor driver modules.

The servo controller contains two essentially identical channels with one channel controlling the right servo motor and the second channel controlling the left servo motor. A minor amount of control exists between the two channels to assure proper synchronization of the steering motors.

During all modes of operation except the flare mode, the analog input to both channels is shorted together by the Control Decoder module. The steering analog input from the control decoder is a bipolar dc with a scale factor of 0.176 volts per inch of steering cord deflection. If the polarity of the input steering analog is positive, a right turn is indicated; if negative, a left turn is indicated. Due to the presence of an operational amplifier performing the function of a precision diode, each channel responds only to the proper polarity of the input signal. This function is performed by operational amplifiers U13 and U14.

The operation of U13 and U14 are identical except for polarity. Each is an inverting rectifier with a DC gain of 1.25 with an output scale factor of 0.176 x 1.25 or 0.22 volts per inch. If the input steering analog is positive in polarity, the output of U13 will be negative and the output of U14 will be zero. If the steering analog input is negative, the output of U14 will be positive and the output of U13 will be zero. Each of these amplifiers also has a zener diode output limiter which prevents its output from exceeding 5.1 Vdc thus limiting the control line deflection to a maximum of 5.1 volts x 0.22 or 23.18 inches.

The right position servo consists of the summing amplifier, U5, the motor driver amplifier, the servo motor, and the position feedback potentiometer.

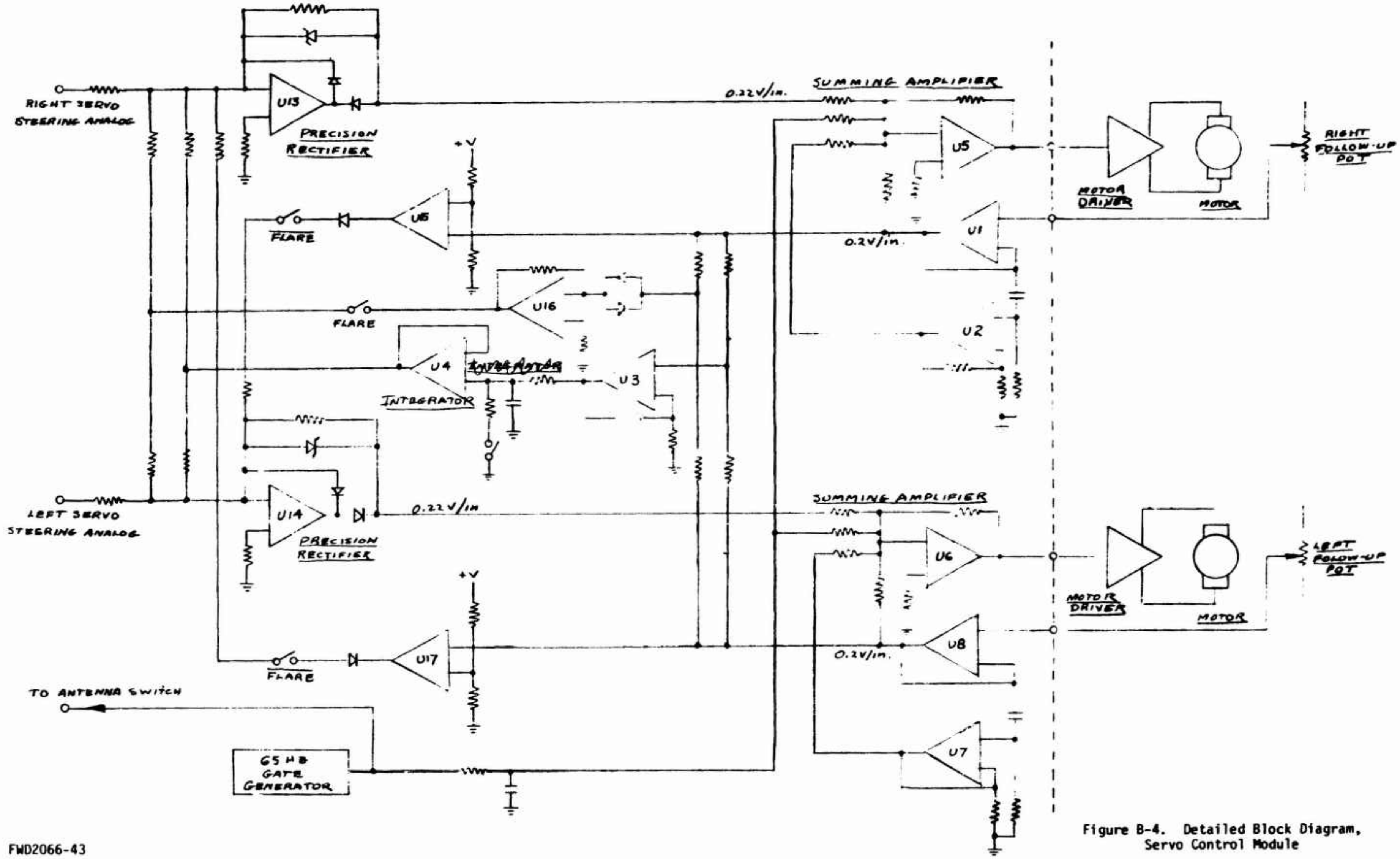

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Figure B-4. Detailed Block Diagram, Servo Control Module

The motor driver amplifier performs as a bridge (H) switch used to control the polarity of the battery drive to the DC permanent magnet motor. The input circuitry to the motor driver amplifier is such that its input signal must exceed a threshold of ±4 Vdc before the motor is switched on. To provide the desired pulse width modulation of the motor current and its resultant efficiency, a four VP-P triangular AC waveform is summed into the output of U5. Small positional errors or commands shift the DC level of this triangular waveform until the peaks of the waveform are equal to the 4 volt DC threshold and very narrow pulses of motor current are produced. Since the DC level of the triangular wave is proportional to the position error of the servo, larger errors place more of the triangular wave above the threshold and wider current pulses are produced. If a saturation error exists, the entire triangular wave is forced above the threshold causing the motor switches to conduct continuously and the motor to run at its maximum rate.

As the slewing motor approaches a null position and the positional error is decreasing, the presence of the triangular wave allows the motor to approach the null with gradually reducing speed. When position errors are reduced to the point that the entire triangular wave is less than the four-volt threshold, diodes within the driver amplifier provide regenerative braking of the motor.

The position feedback potentiometer output is buffered to prevent loading by an operational amplifier U1. The DC scale factor at the output of U1 is 0.2 volts per inch. This signal is fed back to the error amplifier U5 to close the servo position loop. A form of rate feedback is provided by differentiating the position feedback potentiometer output. This differentiated signal is amplified by U2 and summed with the position errors to provide the required degree of damping.

The operation of the left position servo is the same as that described for the right servo.

Under conditions of normal steering, either radial homing or manual steering, it is necessary to prevent both servos from taking in steering cord simultaneously which could happen if, for instance, a left turn command was followed immediately by a right turn command. Operational amplifiers U15 and U17 are used to prevent simultaneous servo operation. If a left turn is commanded before the right servo has returned to zero after a right turn, operational amplifier U15 will provide an override signal to hold the output of U14 to zero. When the right servo has returned to zero, the comparator, U15, will release the override signal leaving U14 free to follow the left turn order. In the same manner U17 is used to hold the right servo at zero until the left sorvo has returned to zero.

When radial homing in the presence of a wind, the ideal apprcach to the target area is similar to a pure pursuit solution which requires a constant or gradually increasing rate of turn. Operational amplifiers U3 and U4 combine to form an integrator used to solve for the turn rate

required to minimize homing deviation angle errors. During any turn, the voltage at the output of the servo followup potentiometers is proportional to the turn rate. The outputs of both servo pots are summed and amplified by U3. The output of U3 is then integrated by an RC network with a 30-second time constant. The voltage stored on the integrating capacitor is then proportional to the average turn rate required to maintain the homing deviation angle at zero. The buffer U4 sums this average turn rate to the steering analog signal. As a result, assuming a perfect solution of the average turn rate, the steering analog input signal will be present only when a turn rate change is required.

During manual steering, the integrator output is reduced to zero by dumping the charge on the integrating capacitor using a transmission gate switch.

During the manual flare mode, the analog steering signals are removed from the controller inputs and replaced with fixed DC voltages which cause both servos to slew to the position of maximum rotation. To equalize the pull on both steering lines, operational amplifier U16 is used to compare the two feedback potentiometer outputs and its output signal is used to retard the leading servo until the control line deflections are nearly equal. When the two servos have equalized, both run at the maximum rate to the full deflection position.

APPENDIX C

ENGINEERING REPORT (INTERIM)
FOR
UHF HOMING ADAPTER
MAGNAVOX MODEL 717-CA

14 DECEMBER 1971

TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION

This report describes the Magnavox Model 717-CA UHF Homing Adapter. General characteristics, installation and operating instructions, and test results are described. Equipment Specification 877493 is included as an appendix.

The 717-CA is a small, lightweight, all solid state UHF homing adapter designed to interface a communications antenna and two spaced blade style antennas with the 713-CA or AN/ARC-150 radio sets. The unit provides homing information, signal strength information, and communication/homing antenna switching in the 225.00 to 399.95 MHz band. The homing adapter is designed to drive display units such as the ID-48/ARN, Sangamo Weston Type 10Q98 cross-pointer or equivalent.

This report is interim and written at this time to provide data useful in evaluating and flight testing the 717-CA. A final report will be issued following formal qualification testing.

2.0 EQUIPMENT DESCRIPTION

2.1 General

The 717-CA is designed to provide UHF homing capability to an aircraft having the Magnavox Model 713-CA radio set or AN/ARC-150 radio set. Homing and signal strength are displayed on a cross-pointer type indicator (not a part of the homing adapter). Homing functions are compatible with most UHF receivers having an ADF capability. Signal strength and flag circuits were designed for 713-CA characteristics and are not generally compatible with other receivers. A sensitivity reduction feature is also included which reduces the homing (vertical) needle deflection to approximately one-half that normally displayed. Outline dimensions are shown in Figure 2-1 and equipment specifications are given in Appendix A.

Homing system interfaces are shown in block diagram form in Figure 2-2. Three antenna inputs are required to allow both communications and homing. The homing adapter includes circuitry to select the proper antenna(s) for a given mode of radio operation. In the COMM mode the homing circuits are inoperative and the R/T is connected to the communications antenna. Selection of the ADF mode on the radio set causes activation of the homing circuits and application of the homing antenna input to the receiver. A ground is also available in this latter condition to allow external switching in the Harrier system where common antennas are used for communications and homing.

All homing circuits except r-f demodulation are contained on three printed circuit boards within the 717-CA. The following sections describe operation of the major circuit functions within the homing adapter.

2.2 RF Circuit Board

This board (Figure 2-3) includes antenna phasing and combining circuits for generating required homing patterns, r-f diode switching for sequentially lobing the antenna patterns, and a relay for transferring between COMM and HOME modes as well as supplying a ground for external relay switching. All external r-f connectors are attached to this board.

The 717-CA operates as a sequentially lobed system in which amplitude modulation is applied to the received r-f signal at a nominal 100 Hz rate. The percent of modulation is determined by the antenna pattern directivities in the direction of the received signal. The indicator display is dependent on the detected modulation level and, therefore, on the antenna directivities. Receiver AGC action removes dependence on signal strength for normal conditions.

The antenna inputs, in the homing mode, are combined through a 90 degree hybrid thus causing the two element array to have an approximate cardioid pattern with maximum either to the left or right of the aircraft (Figure 2-4). The direction of pattern maximum is determined by the hybrid port from which the output is taken. Shape of the antenna pattern is a function of the antenna spacing, frequency, antenna element design, and airframe on which the antennas are mounted. Generally the 717-CA will operate satisfactorily with broadband UHF blade antennas spaced between 7 and 9 inches. Spacing too closely will result in excessive VSWR and distorted patterns at the lower frequencies while too large spacing will cause excessive pattern distortion at the higher frequencies.

The output and terminated ports of the hybrid signal combiner are sequentially interchanged at a 100 Hz rate. The r-f diode lobing circuits, driven by a 100 Hz square wave oscillator, control the pattern lobing and provide the output to the receiver through the COMM-HOME relay. The communications receiver demodulates the received signal and supplies the demodulated 100 Hz to the homing adapter.

The relay is in the COMM position normally and will pass incoming r-f directly between the R/T and communications antenna. Selection of ADF at the receiver causes the relay to connect the homing system r-f to the receiver. The other pole of the relay is normally open but closes to ground potential on ADF selection.

2.3 100 Hz Board

Circuits for generating the 100 Hz square wave and the synchronous audio detector are on a common printed circuit board (Figure 2-3). The demodulated 100 Hz input from the receiver at the wideband audio input is amplified and synchronously compared with the original 100 Hz square wave. The resulting difference is applied to the cross-pointer indicator vertical needle movement. The sensitivity (SENS) and offset (OFS) potentiometer adjustments are electrically connected to this board and control characteristics of the audio amplifier and its input. The sensitivity reduction feature is also included on the 100 Hz board.

The 100 Hz oscillator generates a square wave used both for driving diode switching on the RF circuit board and for synchronously detecting the demodulated audio.

2.4 Power Supply and Flag Driver Circuit Board

This board contains voltage regulation/transient protection circuits for operation of all 717-CA functions. In addition circuits for controlling indicator flags and horizontal (signal strength) needle are on this board.

The homing adapter is powered by +28 volts DC which can be connected to the 717-CA at all times or be switched from the radio set. The homing circuits are activated on selection of ADF at the receiver through providing of a ground return for the DC input voltage. The relay on the r-f board switches from COMM to HOME position at that time. Closing of the transmitter key turns the voltage regulator (and all circuits) off and switches the relay to the COMM position. This prevents transmitting into the homing circuits and connects the transmitter output to the communications antenna.

Indicator flags are made to move out of the display window when a sufficiently strong signal is received to cause the receiver to break squelch. The threshold level is +5 volts. The Magnavox 713-CA radio set has a squelch output of +6 V for no signal and +3 V for the signal valid condition. The flag circuit is also compatible with radio sets which provide a solid ground for signal valid conditions. The squelch input (Pin E of power connector) can be connected to the ADF enable input (Pin H) with other receivers to move the flags out of the window when ADF is selected.

The horizontal needle of the cross-pointer indicator is controlled by the signal strength circuits. This circuit is driven by the receiver AGC and is compatible with the 713-CA only (AGC characteristics vary with the type of receiver). The needle is in its most downward position for weak signals and moves upward to the horizontal with increasing input.

3.0 INSTALLATION AND OPERATING INSTRUCTIONS

3.1 Aircraft Installation

The antenna elements are not a part of the 717-CA homing adapter but their performance and mounting are exceedingly important and often the limiting factor in homing system operation. The antennas must be identical, with equal (as near as possible) input impedance and efficiency. Any difference will result in pattern unbalance and a shift in the measured boresight. Similarly the coaxial cables between the antennas and the homing input ports must be phase matched. Figure 3-1 illustrates cable matching required for two possible system applications. It is further desirable to keep coaxial runs between the antennas and 717-CA as short as is reasonably possible.

Homing adapter performance is measured on a large flat ground plane under near ideal symmetry conditions. Aircraft, however, seldom offer large flat surfaces and often it is difficult to find completely symmetrical conditions about the boresight line. The need for obtaining this symmetry of antenna mounting cannot be overstressed. Mounting off the aircraft centerline or near other protruding objects, such as other antennas, will generally deteriorate performance. The array line of the two antennas used for homing must be normal to the aircraft centerline (Figure 2-4) since the phasing causes the array to be endfire with pattern crossover normal to the array line. Final system performance as well as sensitivity setting can only be determined based on flight evaluation.

3.2 Interconnect Wiring

An interconnect wiring diagram for the homing adapter, antennas, receiver/transmitter, indicator, and sensitivity control is shown in Figure 3-2.

3.2.1 Coaxial Lines

All coaxial line connections utilize TNC connectors at the homing adapter. The R/T is connected through J1 (no color code); the communications antenna through J2 (Blue dot); the left and right homing antennas through J3 (Red dot) and J4 (Green dot) respectively.

3.2.2 Power and Control

The homing adapter is powered and has all non-RF connections through the 19-pin RFI filtered connector J5. The unit is powered by the 28 volt DC aircraft supply lines. This +28 volt line can be connected to pin G of the connector at all times but will normally be switched from the 713-CA radio set. Pin A is a system ground. Total power consumption does not exceed 1 watt.

The homing adapter is operational in the HOME mode and the circuits activated only when the ADF function is selected at the receiver. This selection grounds pin H.

Pin J is connected to the transmitter key line and is grounded whenever the transmitter is keyed. This turns the homing circuits off and transfers the transmitter output to the communications antenna port thus providing transmit protection.

3.2.3 Flag Circuit

The receiver squelch is connected to pin E. A sufficiently strong signal causes the receiver to break squelch and reduce the voltage on pin E from +6 volts (no signal) to +3 volts (signal valid). The FLAG circuits in the 717-CA have a threshold voltage of +5 volts and will cause the flags to move out of the indicator display in the signal valid condition. These circuits will also function with receivers having a solid ground in the signal valid condition. Pin E can be connected to pin H for flag movement whenever the ADF function is selected at the receiver. The flags are connected to pins F and R.

3.2.4 Homing Circuits

The detected 100 Hz modulation is supplied from the receiver wideband audio output to pin D of the 717-CA. This squarewave voltage is amplified and synchronously compared to the original modulating signal, effectively measuring the difference in input between the two lobed antenna patterns. This difference is applied to the indicator vertical movement through pins L and P. A center indication will be observed at the pattern crossover.

Two adjustments are provided for aligning the homing needle indication. Center adjustment for no signal or equal signal inputs is accomplished with the OFS adjustment (Figure 3-3). The adjustment is made to achieve zero deflection for the condition selected. Ideally zero for the two conditions will be identical but a small difference is to be expected as a result of component tolerances, differences in antennas, and antenna mounting asymmetries.

The SENS adjustment allows changing the modulation level at which a full scale meter deflection occurs. This has the effect of changing the physical angle from the aircraft axis at which full scale deflection is observed. A sensitivity reduction feature is provided through pin K which reduces the needle deflection to approximately one-half that in the high sensitivity position.

3.2.5 Signal Strength Circuits

Receiver AGC voltage is supplied to the homing adapter on pin C. The horizontal indicator needle is driven through pins M and N to indicate whether the signal input to the receiver is increasing or decreasing (flying towards or away from the transmitter respectively). The needle is in its most downward position for weak signals and moves upward to the horizontal position for strong signals. No adjustments are necessary or available for this function.

3.2.6 Indicator

An indicator such as an ID-48/ARN or Sangamo Weston type 10Q98 cross-pointer is used with the homing system. The power/control connector interfaces with this instrument through the flag and needle pins previously discussed with the circuits (pins F, L, M, N, P, R). Differences in current ratings between indicators are compensated by adjustment of the SENS potentiometer.

4.0 TEST PROGRAM

4.1 General

Environmental qualification tests have not been conducted for this equipment as of the date of this interim report. As a result, only limited electrical performance data based on initial engineering design is presented. A greater amount of data will be included following formal qualification tests.

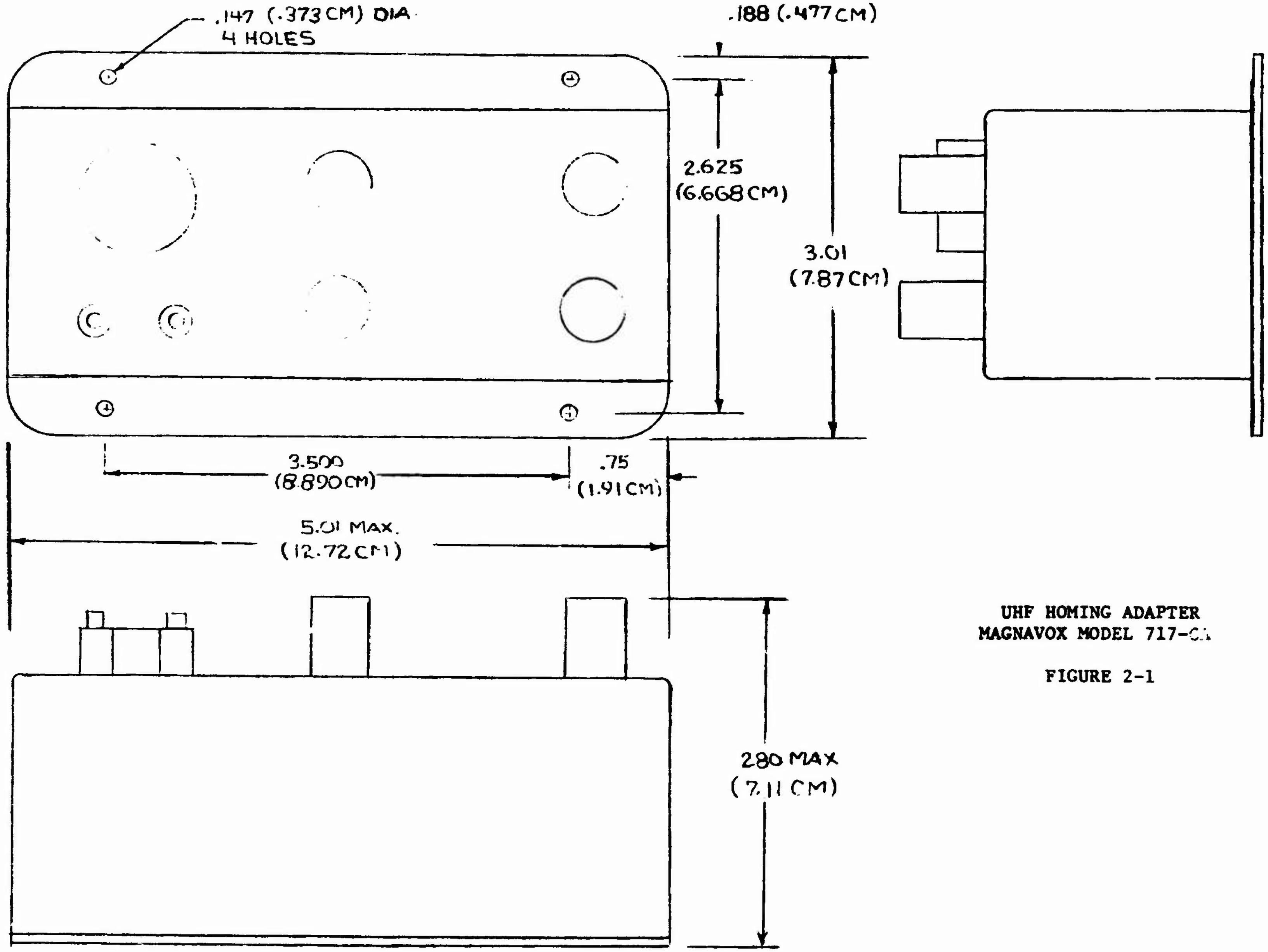
4.2 Specification Compliance

All units are subjected to production acceptance tests as defined in Appendix B. Results are indicated on a data sheet (p. 7 of App. B). Examples of completed data sheets are attached (Figures 4-1 and 4-2) for serial numbers 0003 and 0004. These indicate the typical impedance and insertion loss values to be expected.

4.3 Patterns

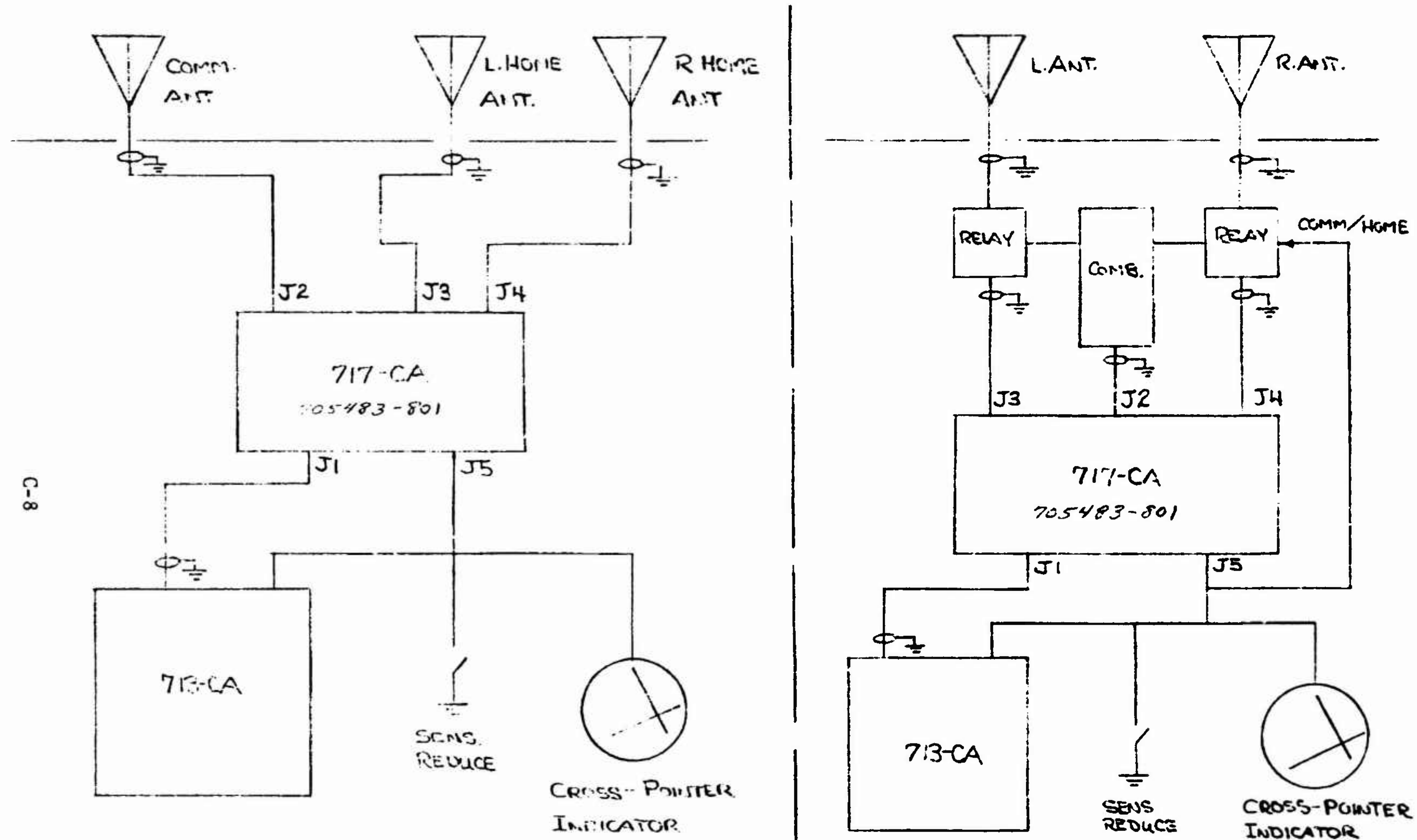
Receiving patterns are measured on a large ground plane range (44 feet x 44 feet) with the receiving antennas mounted on a rotating center and the transmitting antenna at one corner (Figure 4-3). This allows measurement without coupling to feed lines as would occur without a common ground for transmit and receive antennas. The performance of the homing system can then be evaluated under near ideal conditions for performance effects of the various components. It is to be remembered, as noted in Section 3.1, that antenna patterns vary with the ground plane and near-by obstructions so that a flight test program is mandatory for final system performance.

The patterns measured are in the H-plane and are shown for two frequencies in Figures 4-4 and 4-5. Dorne and Margolin UHF blade antennas (DMC7-12A) spaced eight (8) inches were utilized in these tests.



UHF HOMING ADAPTER
MAGNAVOX MODEL 717-C1

FIGURE 2-1



a. SEPARATE COMM.-HOME ANTENNAS

b. COMMON COMM.-HOME ANTENNAS (HARRIER SYSTEM).

FIGURE 2-2. HOMING SYSTEM INTERFACE BLOCK DIAGRAMS.

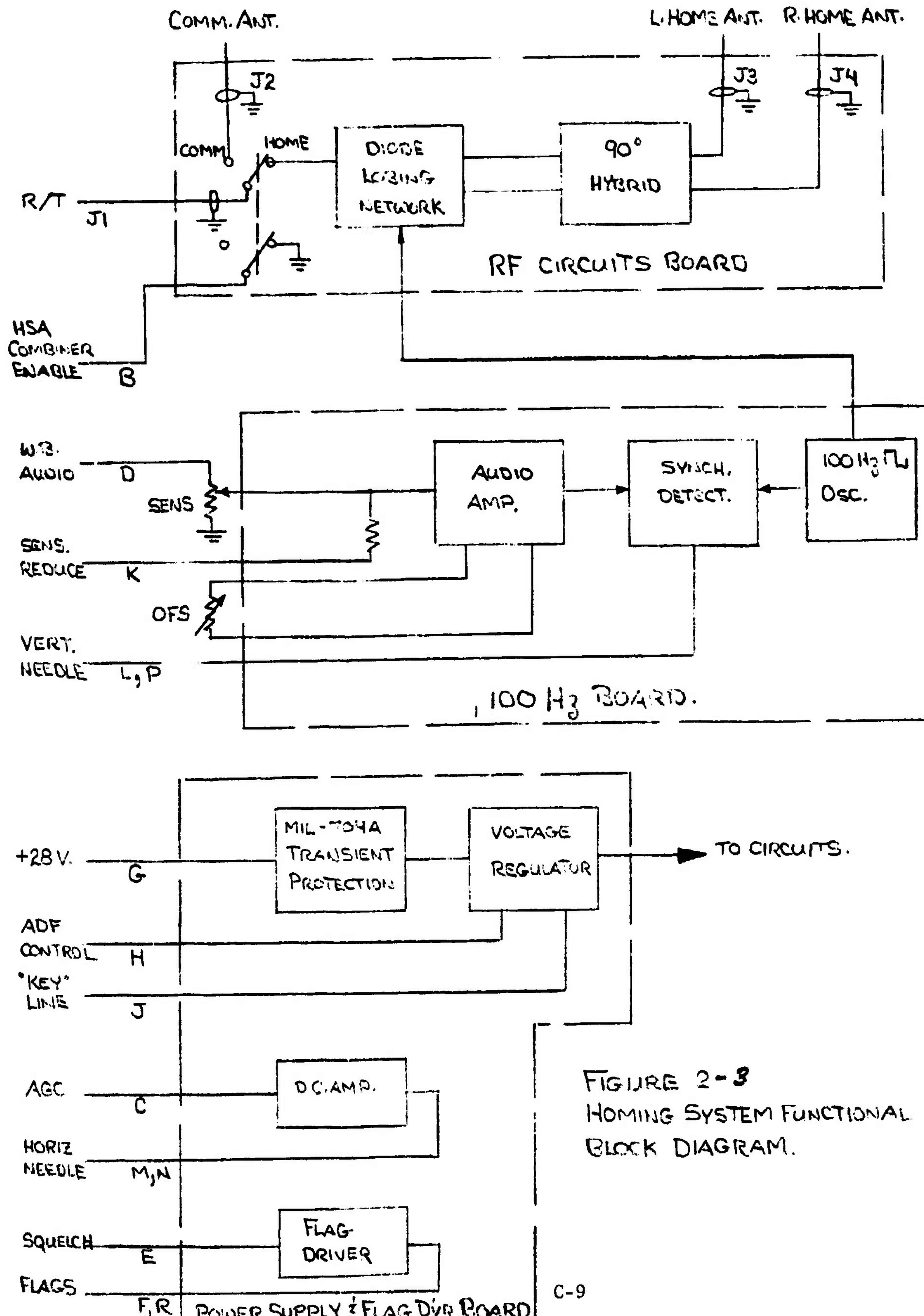
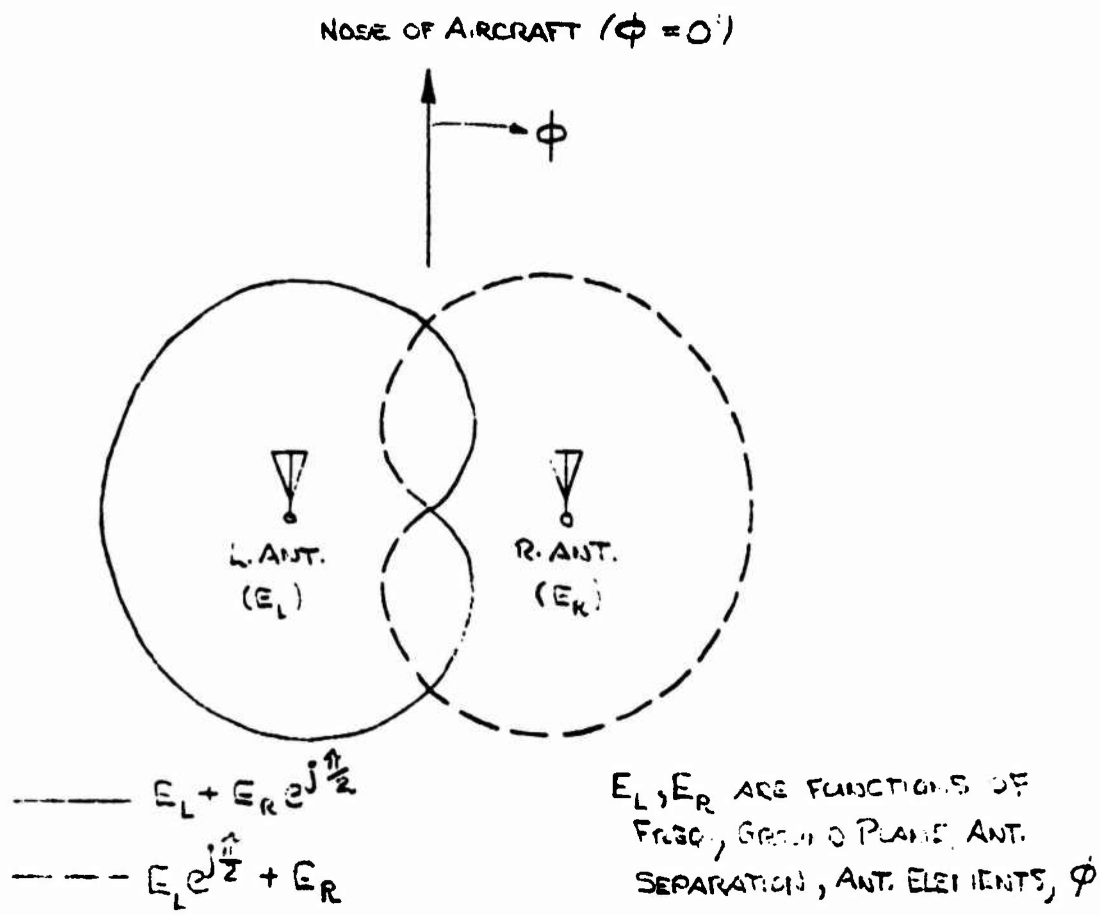


FIGURE 2-3
HOMING SYSTEM FUNCTIONAL BLOCK DIAGRAM.



a. LEFT AND RIGHT PATTERN LOBING

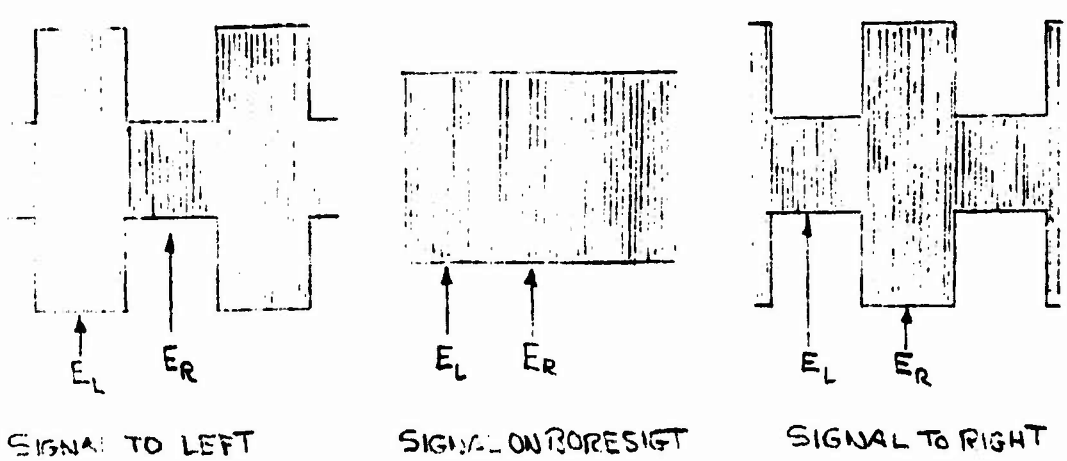
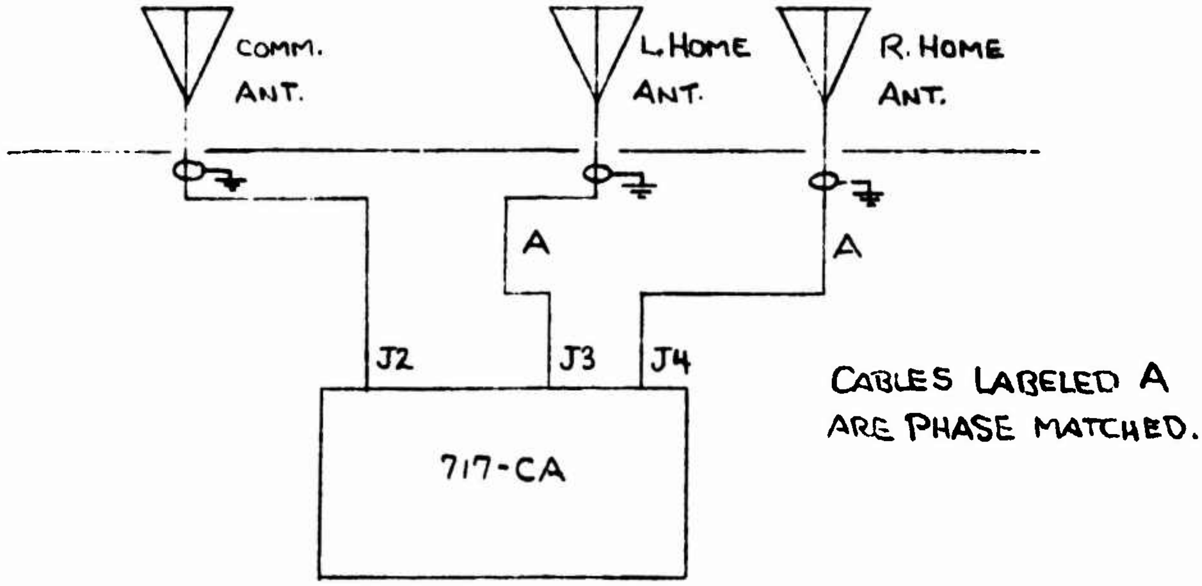
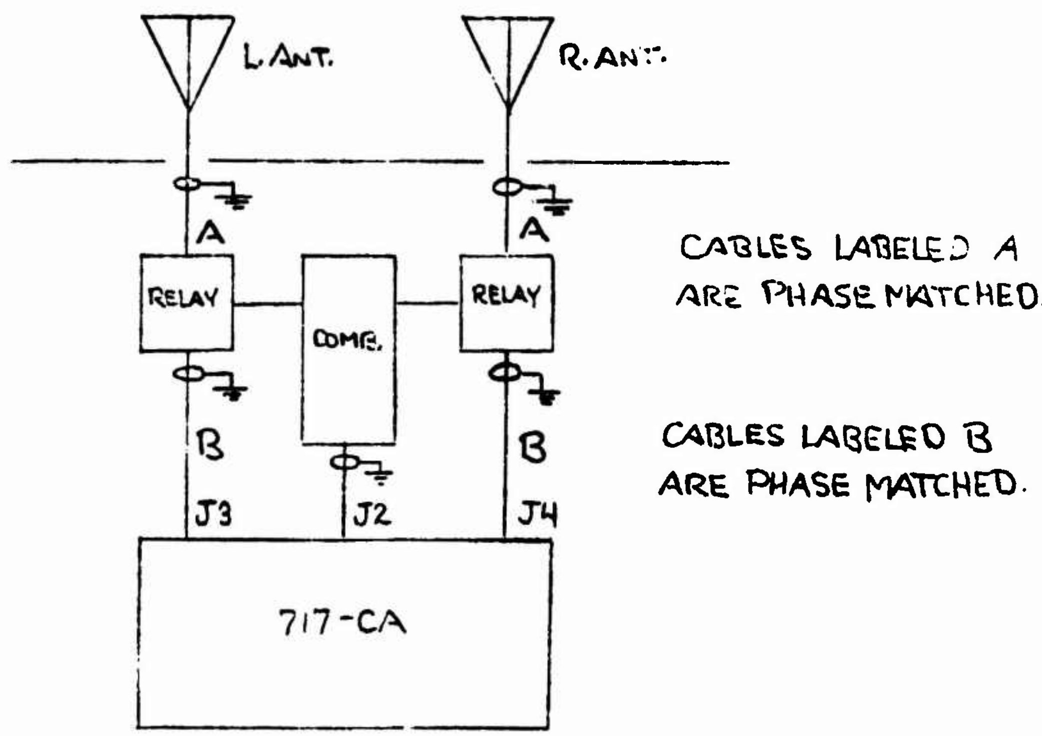


FIGURE 2-4. ANTENNA PATTERN AND LOBING CONCEPT.



a. SEPARATE COMM-HOME ANTENNAS.



b. COMMON COMM.-HOME ANTENNAS.
(HARRIER SYSTEM).

FIGURE 3-1. CABLE MATCHING REQUIRED.

FIGURE 3-3

SPECIFICATION: PRODUCTION ACCEPTANCE TEST

PROCEDURE: INDIVIDUAL TESTS

Production No. 4
Serial No. 0002

DATA SHEET

TEST PARA.	DATA		LIMITS	REF. MX. SPEC. 877493 PARA.
4.0	Initial for compliance LO-Y			4.5.1.1
6.1.3	Input current: 23 ma.		30ma max	3.3.2
6.2	Homing Adapter functions properly with Test Box: Initial for compliance LO-Y			
6.3.1.1	COMM mode VSWR	225 MHz 1.1	2:1 max	3.3.3
		400 MHz 1.15	2:1 max	
6.3.1.2	ADF mode VSWR	225 MHz 1.25	2:1 max	3.3.3
		400 MHz 1.2	2:1 max	
6.3.2	Insertion loss, COMM mode:	225 MHz .2	0.5db max	3.3.4
		400 MHz .3	0.5db max	
6.3.3	Lobing Frequency 103 hz.		75 hz min	3.3.6
			125 hz max	
6.4.1	ARC-150 "KEY" line compatability: Initial for compliance LO-Y			3.1.1
6.4.2	Antenna relay combiner switching ckt: Initial for compliance LO-Y			3.1.2
6.4.4	Indicator Flags: Initial for compliance LO-Y			3.1.3
6.4.5	Horizontal Needle: Initial for compliance LO-Y			3.1.3
6.4.6.2	Vertical Needle -- Gain, Symmetry; Initial for compliance LO-Y			3.1.3
6.4.6.3	Vertical Needle -- Centering: Initial for compliance LO-Y			
6.4.6.4	Vertical Needle: 226 and 399 MHz spot check: Initial for compliance LO-Y			

Lynn O. Yung
Performed by

2-1-72
DATE

SIZE	CODE IDENT NO.	DWG NO.
A	37695	877715
SCALE C-13		SHEET 10 of 10

M301-2 REV 6-64

SPECIFICATION: PRODUCTION ACCEPTANCE TEST

PROCEDURE: INDIVIDUAL TESTS

Production No. 6
Serial No. 0005

DATA SHEET

TEST PARA.	DATA		LIMITS	REF. MX. SPEC. 877493 PARA.
4.0	Initial for compliance ___			4.5.1.1
6.1.3	Input current: 22 ma.		30ma max	3.3.2
6.2	Homing Adapter functions properly with Test Box: Initial for compliance ___			
6.3.1.1	COMM mode VSWR	225 MHz 1.1 400 MHz 1.2	2:1 max 2:1 max	3.3.3
6.3.1.2	ADF mode VSWR	225 MHz 1.2 400 MHz 1.2	2:1 max 2:1 max	3.3.3
6.3.2	Insertion loss, COMM mode:	225 MHz .2 400 MHz .4	0.5db max 0.5db max	3.3.4
6.3.3	Lobing Frequency	106 hz.	75 hz min 125 hz max	3.3.6
6.4.1	ARC-150 "KEY" line compatability: Initial for compliance ___			3.1.1
6.4.2	Antenna relay combiner switching ckt: Initial for compliance ___			3.1.2
6.4.4	Indicator Flags: Initial for compliance ___			3.1.3
6.4.5	Horizontal Needle: Initial for compliance ___			3.1.3
6.4.6.2	Vertical Needle -- Gain, Symmetry; Initial for compliance ___			3.1.3
6.4.6.3	Vertical Needle -- Centering: Initial for compliance ___			
6.4.6.4	Vertical Needle: 226 and 399 MHz spot check: Initial for compliance ___			

Performed by ___   DATE 7-7-72

SIZE	CODE IDENT NO.	DWG NO.
A	37695	877715
SCALE	C-14	SHEET 10 of 10

M301-2 REV 6-64

SPECIFICATION: PRODUCTION ACCEPTANCE TEST

PROCEDURE: INDIVIDUAL TESTS

DATA SHEET

TEST PARA.	DATA	LIMITS	REF. MX. SPEC. 877493 PARA.
4.0	Initial for compliance [illegible]		4.5.1.1
6.1.3	Input current: 19 ma.	30ma max	3.3.2
6.2.2	Antenna relay combiner switching ckt: Initial for compliance [illegible]		3.1.2
6.2.3	Indicator Flags: Initial for compliance [illegible]		3.1.3
6.2.4	Vertical Needle: Initial for compliance [illegible]		3.1.3
6.2.5	Horiz. Needle: Initial for compliance [illegible]		3.1.3
6.2.6	ARC-150 "KEY" line compatability: Initial for compliance [illegible]		3.1.1
6.3.1.1	COMM mode VSWR 225Mhz 1.06:1 400Mhz 1.11:1	2:1 max 2:1 max	3.3.3
6.3.1.2	ADF mode VSWR 225Mhz 1.4:1 400Mhz 1.3:1	2:1 max 2:1 max	3.3.3
6.3.2	Insertion loss, COMM mode: 225Mhz 0.2 400Mhz 0.0	0.5db max 0.5db max	3.3.4
6.3.3	Lobing Frequency: 105 hz.	75 hz min 125hz max	3.3.6

Assembly #1

Ser #0003 Before shipping.

[illegible signature]

11-24-71

Figure 4-1.

SIZE	CODE IDENT NO.	DWG NO.
A	37695	877715
SCALE	C-15	SHEET 7

M301-2 REV 6-64

TP 3114-10
71-10-1156
71-10-1154

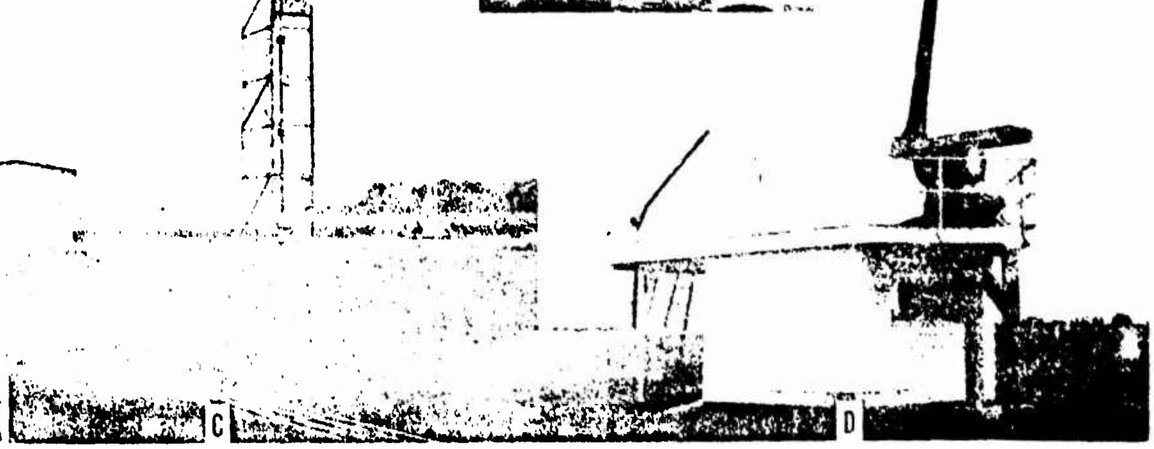
A. Testing at turntable at center of a Ground Plane Range

B. Overall view of a Ground Plane Range

C. Transmit Tower for a model range including polarization positioner and transmitter house

D. Model positioner and control room

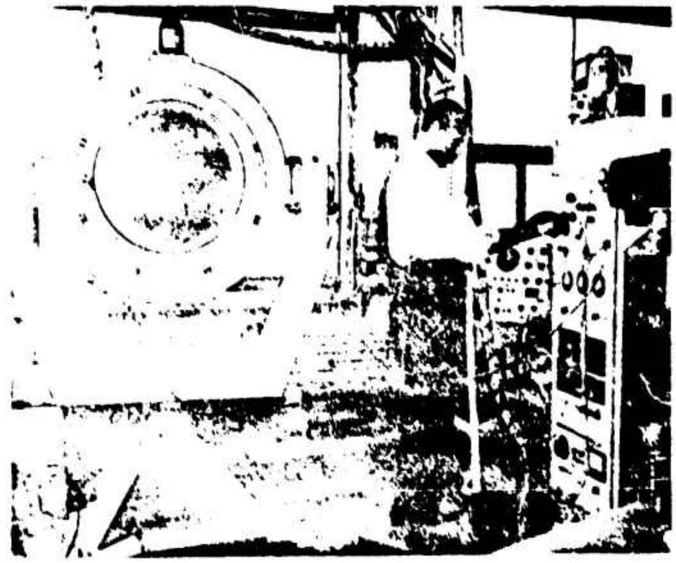
E. View of equipment inside the control room

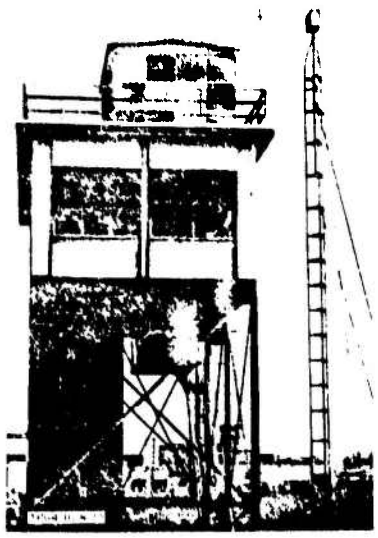


TP 3114-11
71-10-1157
71-10-1151
71-10-1153

FIGURE 4-3

Internal view (right) of a positioner for a Radar Boresight Range; and External View (below) of Radar Boresight Range.





RADAR TEST RANGE

The radar test range is used for the evaluation of radar antennas and systems. Active and passive targets, pattern range elements, and boresight grids are installed at ranges from 50 feet to 7 miles from the main test tower.

IMPEDANCE MEASUREMENT

Modern equipment at Magnavox measures impedance in the design of antennas and coupling systems. There is a swept frequency measurement capability with network analyzers for the frequency range of 100 kHz through 12.4 GHz. Vector impedance meters and vector voltmeters are used for both field laboratory measurements below 1000 MHz. The usual slotted line and reflectometer techniques are also utilized in microwave measurements. In some cases, bridges and reflectometers are used to evaluate portable antennas when transmission lines cause excessive errors in measurements by laboratory instruments.

THE Magnavox COMPANY — SHEET ___ OF ___

ANTENNA 717-CA w/ DMC7-12A Spaced 8 — SCALE 1:1 — SCALE FREQ. 2251MHz
PROJECT 717-CA — DATE 12/13/71
REMARKS

POLAR RECORD (VOLTAGE PLOT)

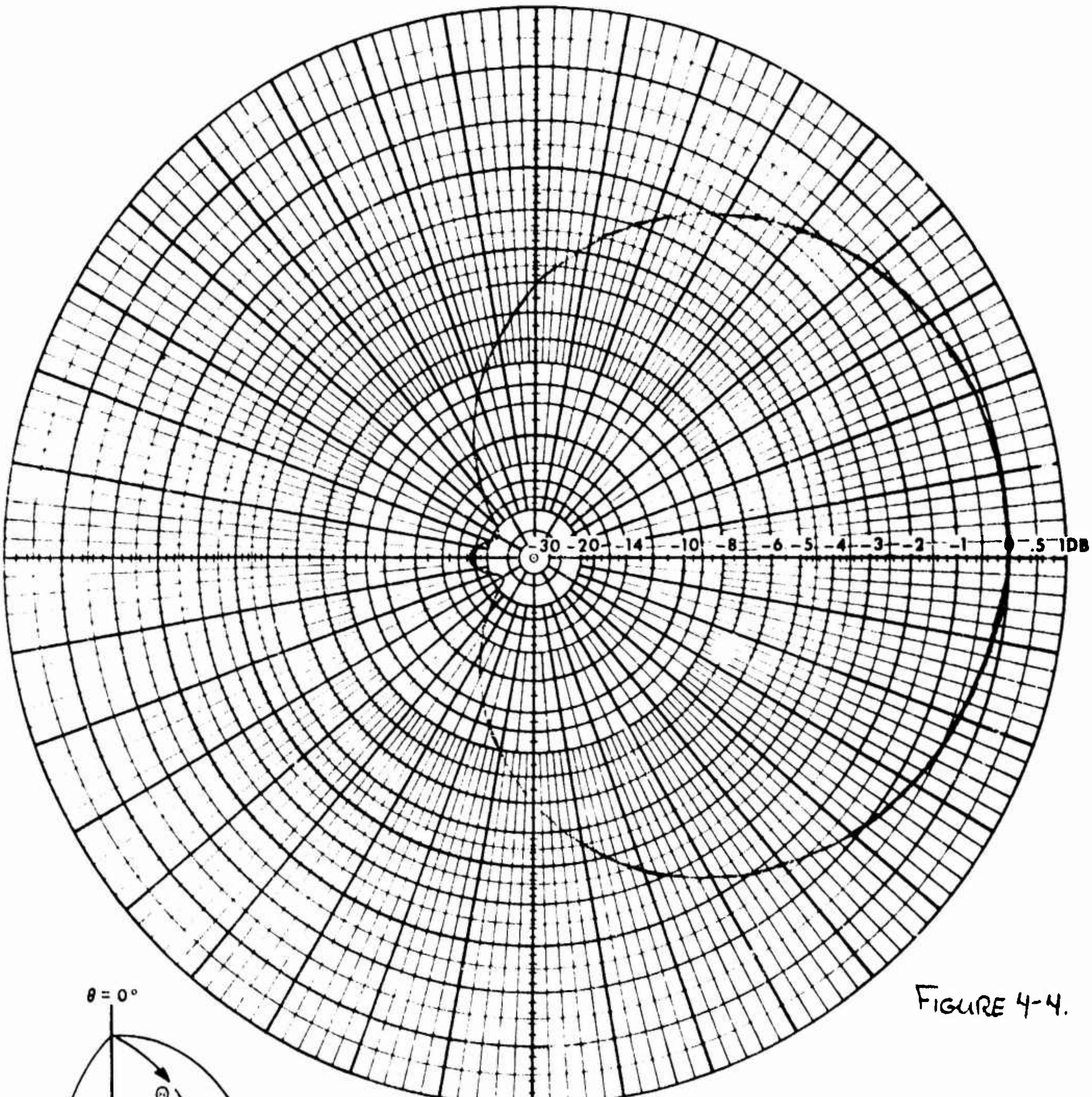
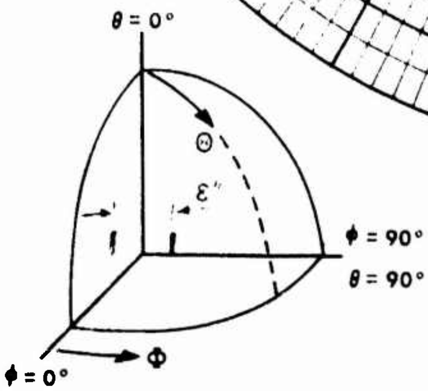


FIGURE 4-4.



POLARIZATION E_ϕ ___, E_θ ✓, ___
VARIABLE ANGLE Φ ✓, Θ ___
CONSTANT ANGLE φ = ___, θ = 90°
TECH RTT — ENGR L GERIG

THE **Magnavox** COMPANY SHEET ___ OF ___

ANTENNA 717-CA w/DMC7-12A Spaced 8"	SCALE 1:1 SCALE FREQ. 400 MHz
PROJECT 717-CA	DATE 12/[illegible]
MARKS	

POLAR RECORD (VOLTAGE PLOT)

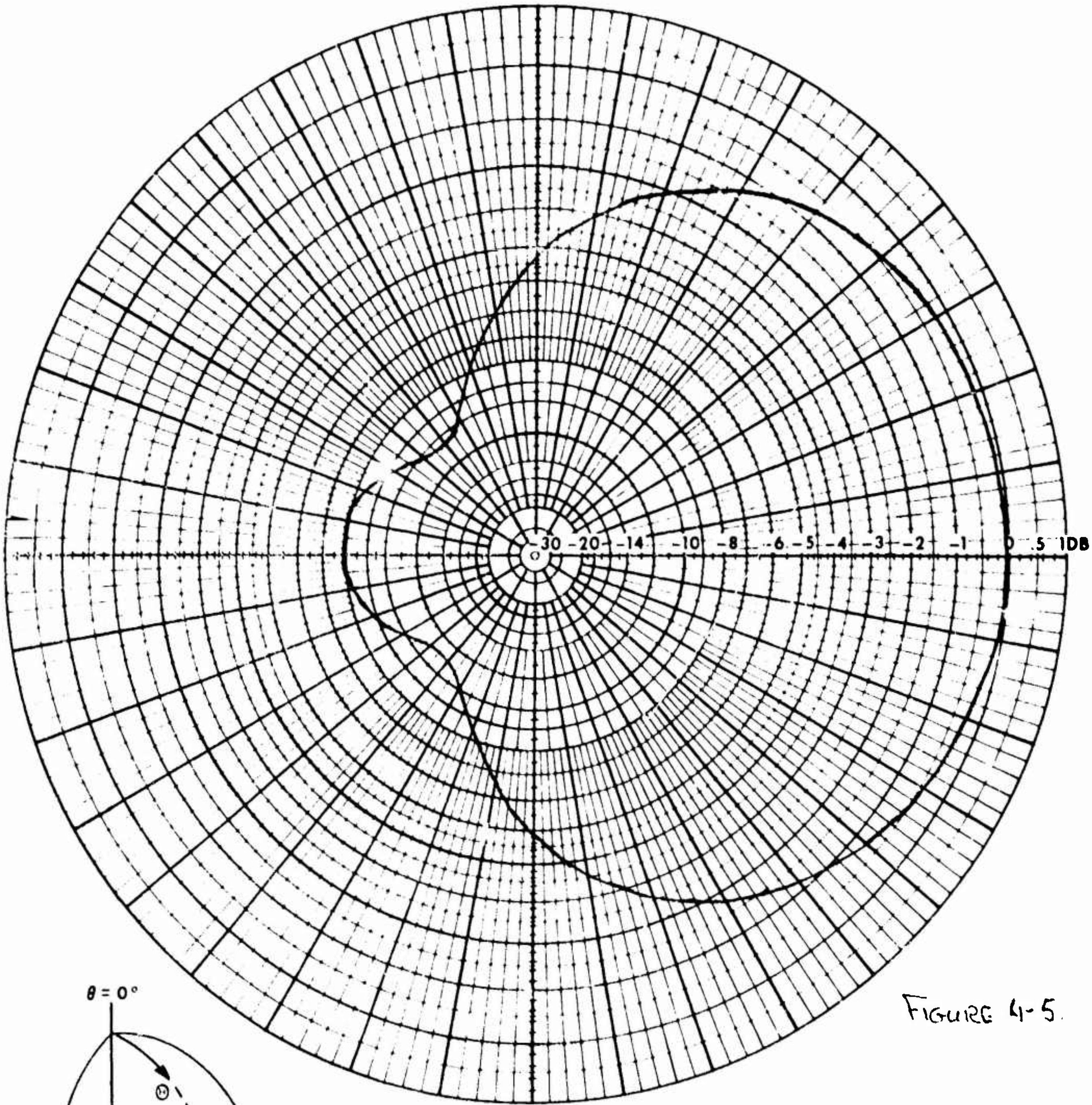
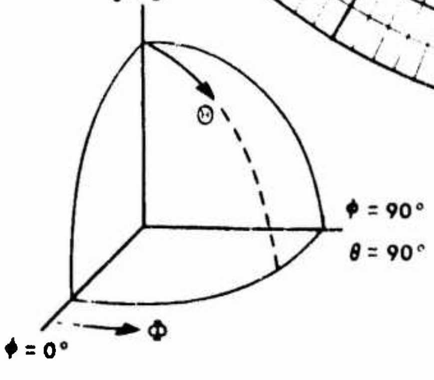


FIGURE 4-5.



G-1970-20

POLARIZATION E_ϕ ___ E_θ ✓ , ___	
VARIABLE ANGLE Φ ✓ , Θ ___	
CONSTANT ANGLE ϕ = ___ , θ = 90°	
TECH SET	ENGR L.G. Rig

APPENDIX D

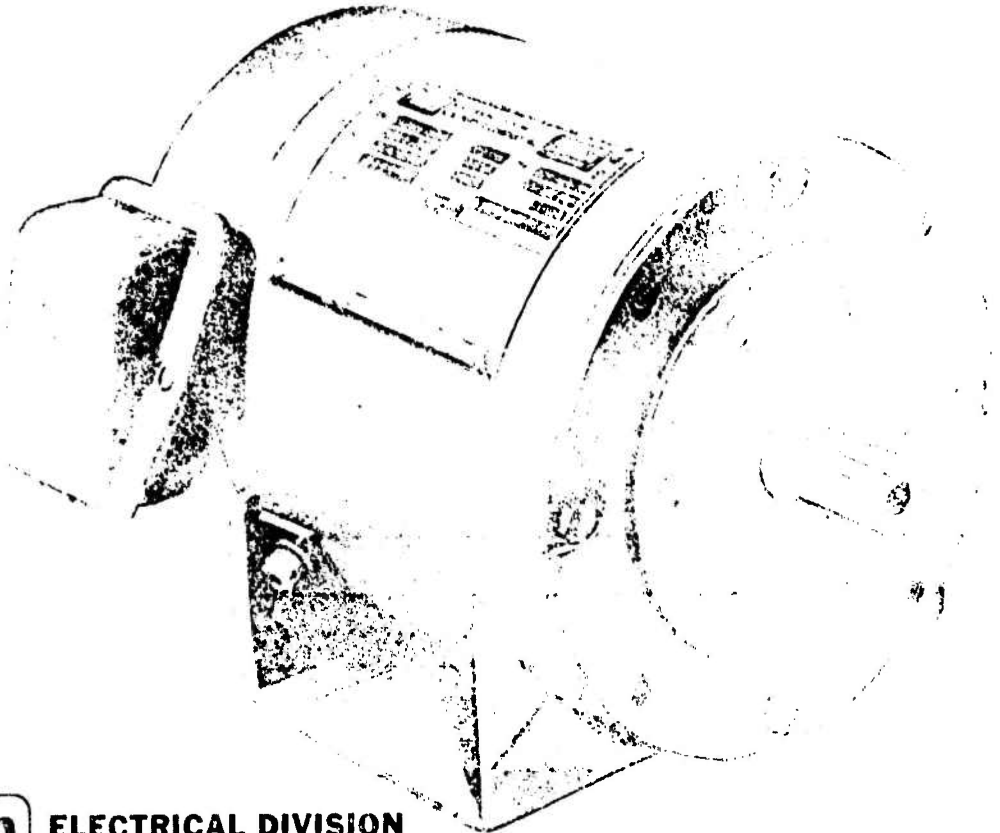
SERVO MOTOR, CONTROLLER, AND BATTERY VENDOR DATA

PEERLESS ELECTRIC

CATALOG 60-200
Issue No. 2 July 1973

Supersedes Issue #1
April 1972

5610 Series General Purpose DC Permanent Magnet Motors



PORTER ELECTRICAL DIVISION
H. K. PORTER COMPANY, INC.

Peerless Electric 5610 Series permanent magnet D. C. motors incorporate the latest technologies in oriented strontium ferrite ceramic magnets, and pressed steel frame electric motor construction. These features make the 5610 Series an excellent selection in high torque, heavy-duty industrial drive applications. In designing this product, Porter engineers performed the task with SCR rectified power in mind. The result is a unique combination of high coercive force ceramic magnets, low inductance armature, low bar-to-bar commutator voltage and specially selected brush materials that optimize commutation on high form factor SCR non-regenerative drives. Performance alone is making the 5610 Series first choice for adjustable speed drives where precise positioning and speed variation are required.

FEATURES:

Rugged all-steel construction ▪ Class F insulated armature ▪ Versatile bolt-on mounting base ▪ Dynamic braking in power-off mode ▪ Pulse torque 5 times rated torque ▪ "C" type face mounting ▪ Linear speed/torque/amperes characteristics ▪ High reliability... no field coils ▪ Totally enclosed non-ventilated ▪ Two terminal input simplifies control circuitry ▪ High horsepower to weight ratio ▪ Skewed armature for smooth low speed operation ▪ High torque-to-cost ratio ▪ Large double shielded ball bearings ▪ the 5610 Series P.M. Motors

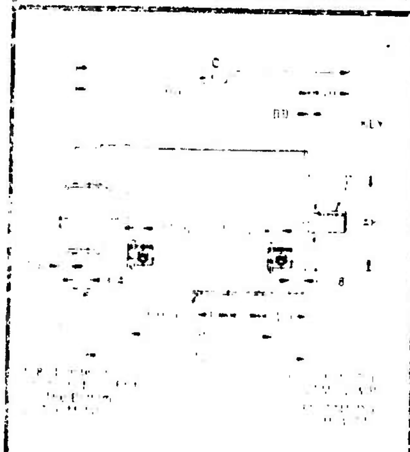
Permanent Magnet D.C. Motor Frame Assignments Based Upon 90 and 180 V D.C., Single Phase, Full Wave, Rectified Supply, 1750 R.P.M. Base Speed, Continuous Duty 40° C, Ambient

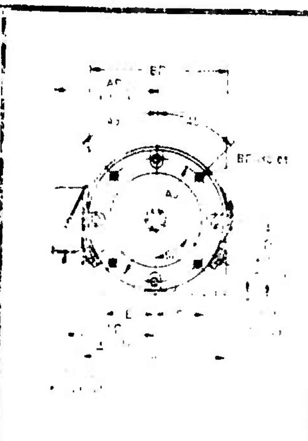
HP @ 1750 R.P.M.	Frame Size	Rectified Volt. Sply.	Rated F.L. Amps.	Max. Pulse Amps.**
¼	DPM56DG2*	90 VDC	2.7	80
⅓	DPM56DG2*	90 VDC	3.5	80
½	DPM56DG2*	90 VDC	5.25	80
¾	DPM56PG2	90 VDC	7.9	145
1	DPM56PG2	90 VDC	10.5	145
¾	DPM56PG2	180 VDC	4.0	73
1	DPM56PG2	180 VDC	5.3	73
1½	DPM145TZG2*	180 VDC	8.0	120
2	DPM145TZG2*	180 VDC	10.5	120

[illegible] E, AH & BA [illegible] from NEMA standards [illegible] drawing

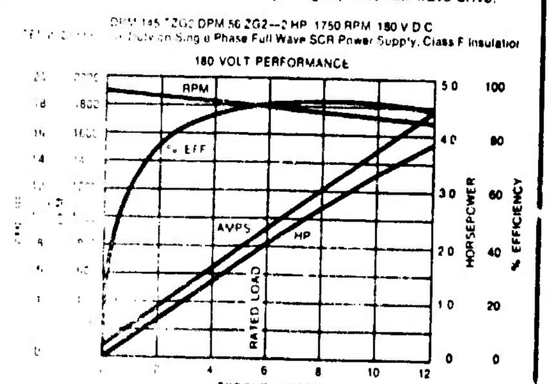
** [illegible] will cause [illegible] in permanent magnet flux and hence motor performance.

Motor Weight: DG2 [illegible] PG2 [illegible] TZG2 [illegible]





Typical performance curves Frame DPM 145TZG2, 2 HP, 1750 RPM Class "F" insulation, cont. duty, single phase full wave drive.

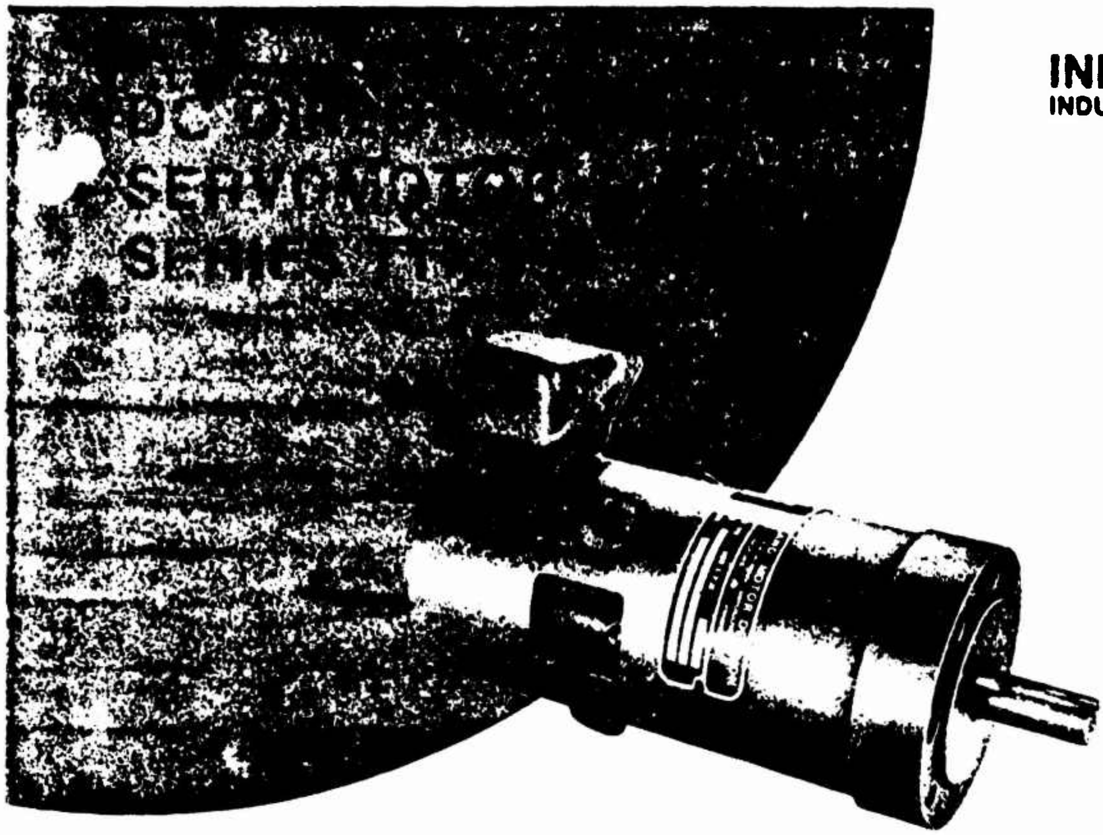


FRAME	A	B	C	AD	AB	AC	E	H HOLES	F	D	AG	AH	AJ	AK	BA	BB	BD	BF	KEY
DPM56D	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2⅞	⅛	6¼	⅜-16	$^3/_{16}$ SQ. x 1⅜
DPM56P	7	7	13⅞	[illegible]	5⅝	4¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	4½	2¾	⅛	6¾	⅜-16	$^3/_{16}$ SQ. x 1⅜
DPM145TZ	7	[illegible]	15$^{15}/_{16}$	[illegible]	5⅝	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4½	2¼	⅛	6¾	⅜ 16	$^3/_{16}$ SQ. x 1⅜

NOTES: 1. AK Tolerance: .000-.003
2. [illegible] Runout: .010 T.I.R. Max
3. Mtg. Dia. Runout: .010 T.I.R. Max
4. Shaft Runout: .002 T.I.R. Max

Tolerances Unless Otherwise Specified: Casting to Casting ± 1/16; Casting to Finish ± 1/32; Fin. Fractions ± .010; Fin. Decimals ± .005; Unified Thd Class 2; Angular Tol. [illegible] All Radii and Fillets are 1/16 Unless Noted

5610 FRAME	DATA SHEETS	STALLED TORQUE LB.IN. TENV	B.C.	TORQUE CONSTANT LB.IN./AMP	VOLTS AT 1000 RPM	N.L. SPEED @ 85V	ARM. RES. OHMS	ARM. IND. M.H.	AMPS AT PEAK TORQUE	ARMATURE POLAR INERTIA LB.IN.SEC.^{2}	MOTOR WEIGHT POUNDS
[illegible]	E-8569	60.		2.9[illegible]	34.76	2450	.1[illegible]	1.[illegible]96	38.0	[illegible]	41.
[illegible]	F-8[illegible]0	60.		3.[illegible]	31.71	2025	[illegible]	[illegible]	[illegible]	[illegible]	41.
[illegible]	[illegible]98	60.		4.115	[illegible]69	1750	[illegible]	[illegible]	63.0	[illegible]	41.
[illegible]	[illegible]	60.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55.0	.11[illegible]	41.
[illegible]	[illegible]	60.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49.0	[illegible]	41.
[illegible]	[illegible]597	[illegible]0.		5.880	69.53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41.
[illegible]	[illegible]	60.		2.[illegible]	[illegible]	3000	[illegible]	[illegible]	[illegible]	[illegible]	58.
[illegible]	[illegible]	75.		3.526	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.
[illegible]	E-8790	9[illegible].		4.690	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.
[illegible]	E-87[illegible]2	110.		5.[illegible]76	69.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.



INLAND MOTOR
INDUSTRIAL DRIVE DIVISION

- **3 Basic Sizes: 1-2 HP (TENV); 4 HP (Accel/Decel)**
- **Torques: 1.5-3-6 lb. ft (TENV)**
- **Up to 5000 rpm max. speed**

Power with Precision

Utilizing high energy rare earth magnet meteriel, the TT29.5 series DC servomotor-tach units provide precise motion control in machine-tool feed-drive applications. Their superior constuction and performance however, makes them an ideal servoectuator for other industrial uses such as automatic material handling, wire-drawing, paper plastic-film eno foil processing, tension controls and packaging machinery, etc. Peak torque of 30 lb. ft gives ample power for fast, accurate positioning. Coupled with low motor inertia theorelical acceleration of up to 25000rad/sec^2 results.

With a speed range capability in excess of 20,000: 1 one motor can provide rapid traverse end feed rales for each mechine axis, eliminating the complexity and compliance of multiple motors, clutches and gear trains. Speeds as low as 6 revs. per hour mey be achieved in a position loop without cogging.

The unique permanent-magent structure eliminates thermal runawey and commutation problems commonly encountered in conventional ceramic-magnet motors.

Design Options Available

Designers have a wide choice of modular options available with this unique motor . . . all integrally built into one compact unit.

The feedback resolver module uses precision gearing that delivers position information with consistent accuracy. The one-pass geer drive off the motor shaft eliminates compliant gear trains and couplings, minimizing backlash. The resolver module is sealed to exclude dust, oil, or other conteminents.

The 6 lb. ft. electro-magnetic disc brake is mounted directly on the drive shaft for emergency and "parking" brake applications; the motor is stopped in less than 2 revolutions from 1000 rpm, depending upon reflected load inertia. Power OFF/Brake ON action is inherently fail-safe in the event of power failure.

System Capability

TT-295X series motor-tachs are power-matched for use with Inland's single and three-phase SCR drives or Inland's HYBAND PWM transistor amplifiers.

Specifications

Motor Parameters (DC)

Parameter	Tol.	Symbol	Units	TT-2950 A	TT-2950 B	TT-2950 C	TT-2952 A	TT-2952 B	TT-2952 C	TT-2952 D	TT-2953 A	TT-2953 B
Horsepower	Rated	hp	hp	1.0	1.0	1.0	1.2	1.2	1.0	1.2	1.6	2
Max operating speed	Max	ωmax	rpm	5000	5000	4500	3000	2500	2000	3000	2000	3000
Continuous torque (stall) @ 40°C ambient	Nom	Tc	lb • ft	1.5	1.5	1.5	3.0	3.0	3.0	3.0	6	5.8
			N • m	2.0	2.0	2.0	4.07	4.07	4.07	4.07	8.14	7.86
Peak torque	Nom	Tp	lb • ft	9.5	11.0	12.0	20.0	22.0	25.0	20.	30	22
			N • m	12.9	14.9	16.3	27.1	29.8	33.9	27.1	40.7	29.8
Theoretical acceleration	Nom	α M	rad/sec²	13670	15827	17266	20,000	22,000	25,000	20,000	14850	10890
Current @ cont. torque	Rated	Ic	amps	11.72	9.74	8.33	11.3	9.36	8.04	11.3	15.8	21.4
Current @ peak torque	Rated	Ip	amps	90	90	90	90.0	90.0	90.0	90.0	90	90
Max. terminal voltage	Max.	VT	volts	115	115	115	115.0	115.0	115.0	115.0	115	115
Torque sensitivity	±10%	KT	lb • ft/amp	0.128	0.154	0.180	0.266	0.320	0.373	0.266	0.380	0.271
			N • m/amp	0.174	0.209	0.244	0.361	0.434	0.506	0.361	0.515	0.368
Back EMF constant	±10%	KB	V/k rpm	18.2	21.9	25.5	37.8	45.4	52.96	37.8	53.95	38.48
DC resistance @ 25° C	±12.5%	RM	ohms	0.321	0.484	0.712	0.452	0.68	1.0	0.452	0.393	0.199
Inductance	±30%	LM	mH	0.92	1.3	1.8	1.6	2.5	3.2	1.6	1.8	0.81
Time constant @ 25° C, Mech.	Nom	TM	msec	8.9	9.3	10.0	5.6	5.6	6.3	5.6	4.7	4.7
Time constant @ 25° C, Elec.	Nom	TE	msec	2.9	2.7	2.5	3.5	3.7	3.2	3.5	4.1	4.1

Tachometer Parameters

Parameter	Tol.	Symbol	Units	TT-2950 A	TT-2950 B	TT-2950 C	TT-2952 A	TT-2952 B	TT-2952 C	TT-2952 D	TT-2953 A	TT-2953 B
Voltage sensitivity	±10%	KG	V/k rpm	12.5	12.5	12.5	12.5	12.5	12.5	20.0	12.5	12.5
Volt. ripple @ 25 c/s ...	Max	/=	% avg-pk	3	3	3	3.0	3.0	3.0	3.0	3	3
DC resistance	±12.5%	RG	ohms	18	18	18	18.0	18.0	18.0	44.0	18	18
Load resistance	Min	RL	ohms	2K	2K	2K	2K	2K	2K	4.4K	2K	2K
Inductance	±30%	LG	mH	22	22	22	22.0	22.0	22.0	58.0	22	22

Basic Motor-Tachometer Constants

Parameter	Symbol	Units	TT-2950	TT-2952	TT-2953
Rotor inertia	JM	lb • ft • sec²	6.95 x 10⁻⁴	1.0 x 10⁻³	2.02 x 10⁻³
		kg • m²	9.42 x 10⁻⁴	1.4 x 10⁻³	2.74 x 10⁻³
Weight	Wt	lb	16.5	21.9	31.7
		kg(f)	7.5	9.9	14.4
Static friction	TF	lb • ft	0.16	0.22	0.32
		N • m	0.22	0.30	0.43
Thermal time constant	TCT	minutes	35	55.0	75
Viscous damping (∞ Z source)	Fi	lb • ft/k rpm	0.027	0.055	0.112
		N • m/k rpm	0.037	0.075	0.152

Application Information

The "Performance Curve" defines the normal limits of reliable operation on pure DC. The "Intermittent Duty" zone exploits the high thermal capacity of these motors, enabling high torque loads to be used on a duty-cycle basis. The "Accel/Decel" zone defines the acceptable commutation levels for rapid motor acceleration and deceleration.

For operation with SCR drives the relevant torque ratings must be derated by the appropriate form factor (FF). Form Factors range from 1.4 for 1∅ full-wave, 1.2 for 3∅ half-wave, to 1.05 for 60 half-wave. For PWM amplifiers form factor is effectively 1.0

The "Rated HP" curve defines operating points within which a nominal 15,000 hours of brush life may be expected at commutation levels ranging from 1.5-2.0. For operation at other HP levels, brush life varies approximately inversely to the square of the ratio of Operating HP to Rated HP (with appropriate consideration of thermal capacities).

All DC Permanent Magnet motors require current-limited drive amplifiers to ensure that brush current densities do not exceed the maximum allowable levels for reasonable brush and commutator life. The Accel/Decel curve shown is the recommended maximum current limit to provide crisp accel/decel while maintaining brush/commutator integrity.

Although designed for direct-coupling, the designer has great latitude of choice of ball screw pitches and gearing. Occasionally it may be desirable to gear the motor to the load to couple small motors to large loads. (The maximum motor speed should not exceed motor rating). For cases where accel/decel is a large percentage of total cycle time, gearing to match the reflected load inertia to motor inertia optimizes the work-output from the motor.

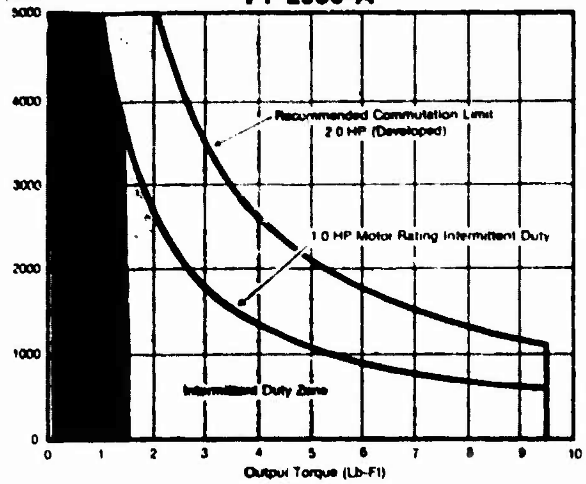
The optimum gear ratio N is given by

$$N = \sqrt{\frac{J_L}{J_m + J_G}}$$

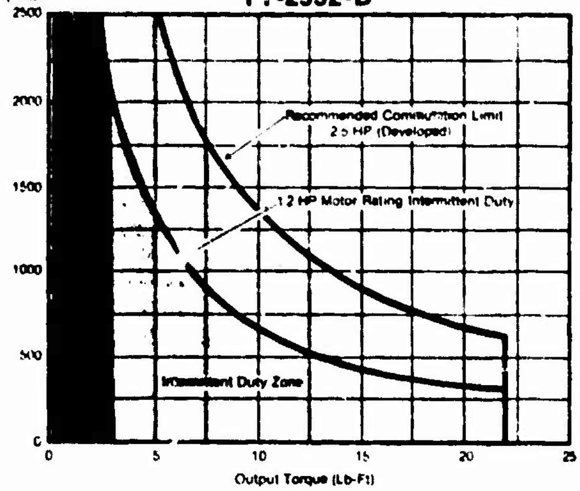
where J_L = total load inertia
J_m = motor inertia
J_G = motor pinion inertia

PERFORMANCE CURVES

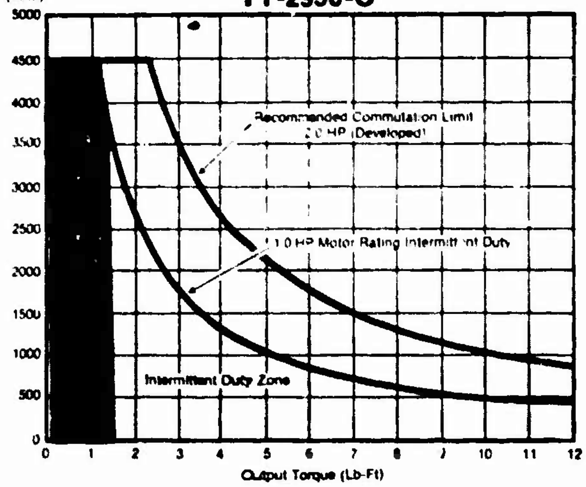
TT-2950-A



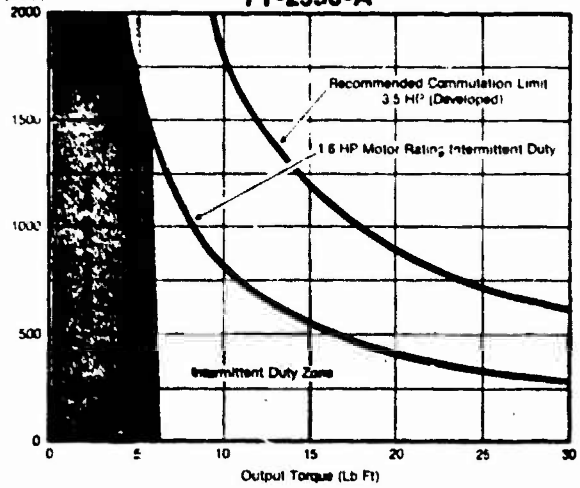
TT-2952-B



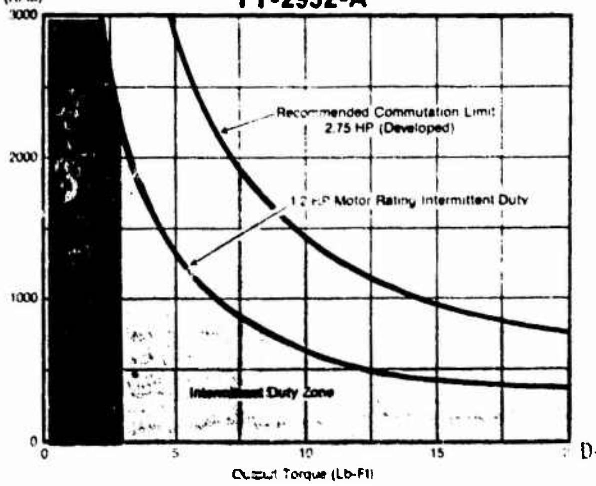
TT-2950-C



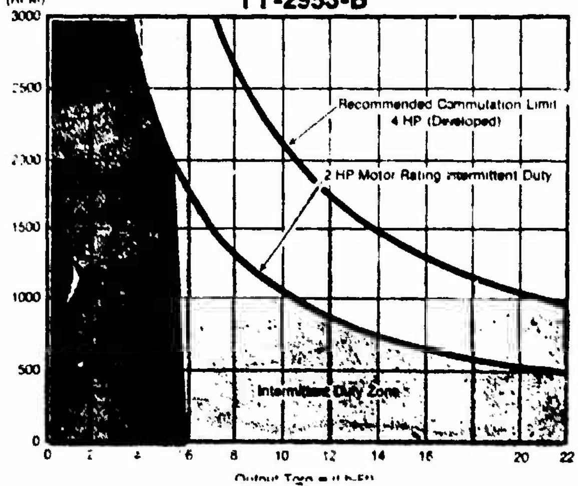
TT-2953-A



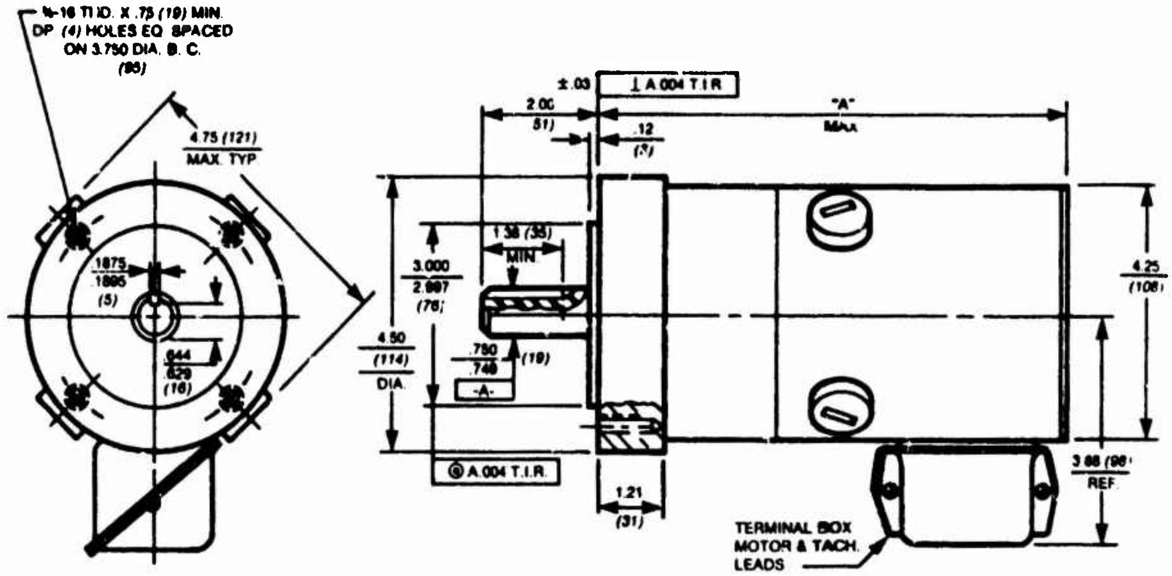
TT-2952-A



TT-2953-B



MECHANICAL SPECIFICATIONS



NOTE:
1. SHAFT DIA. "A" RUNOUT WILL NOT EXCEED .002
2. ALL DIMENSIONS IN INCHES WITH METRIC EQUIVALENTS IN PARENTHESIS
3. WITH A POSITIVE CURRENT APPLIED TO GREEN LEAD WITH RESPECT TO ORANGE LEAD, MOTOR ROTATION SHALL BE C.W. FACING MTG END. WITH THIS ROTATION A POSITIVE VOLTAGE SHALL BE GENERATED ON BLACK LEAD WITH RESPECT TO WHITE LEAD OF TACHOMETER.

MODEL LENGTH

MODEL	TT-2950	TT-2952	TT-2953
Length "A" Inches (MM)	8.25 (210)	9.7 (246)	12.6 (320)

OPTIONS

OPTION NUMBERING SYSTEM

Torquer Tachometer	Resolver	Brake		Frame Size		Mechanical Variation		Electrical Winding		Resolver Gear ratio		Resolver Type
TT	R	B	–	295X	–	0000	–	A	–	YY	–	A

BRAKE MODULE

A fall-safe electromagnetic disc brake can be integrally mounted on the motor shaft immediately behind the front mounting flange. The brake module adds less than 2.5 inches to the length of the motor. The brake module operates in the Power ON/Brake OFF mode providing both continuous static "parking" and emergency brake capability.

Brake torque (static): 6 lb. ft. (nom.)
Brake torque (dynamic): 4 lb. ft. (min.)
Coil Power: 115 VAC 50/60 hz. Holding current: 0.75A, Inrush 8.0A
Drop-out time: 10 ms. (nom.) (Brake Engage)
Pull-in time: 200 ms. (nom.) (Brake Disengage)
Shaft backlash: 10 arc-minutes (a more expensive zero-backlash brake is available on request.)

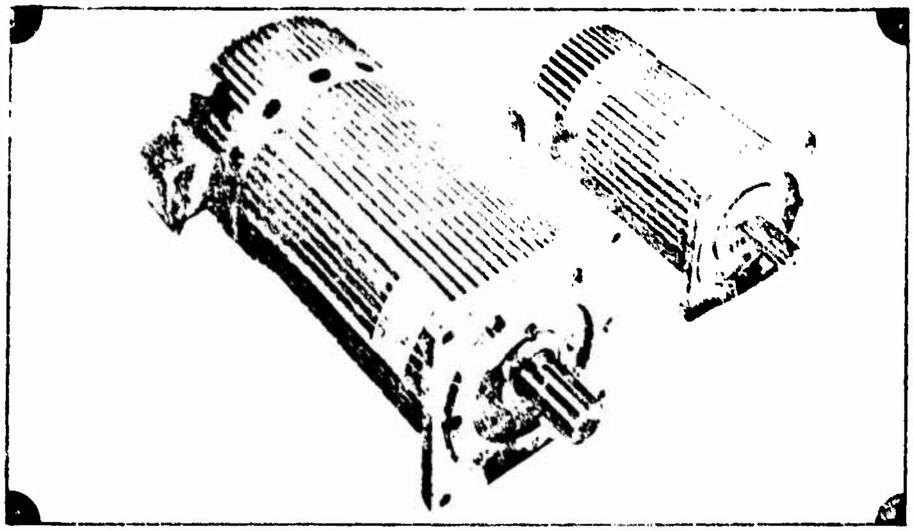
RESOLVER MODULE

A standard size 11 brushless resolver, coupled to the rear-end shaft via a precision instrument gear-train is available for all models, for use as a position feedback transducer. Gear ratios compatible with the majority of NC systems and lead-screw pitch combinations can be selected.

Standard resolvers offered are
Harowe 11 BHW-300-B-1 (10 arc-min. res. 400 Hz)
Kearfott CR 40931019 (10 arc-min. res. 400 Hz)
Harowe 11 BRW-300-F-1/3 (3 arc-min. res. 2.5 KHz)
Kearfott CR 41095004 (3 arc-min. res. 2.5 KHz)

Other size 11 resolvers or size 23 optical encoders can be provided on request; special machining and mounting may be required.

PEERLESS ELECTRIC Direct Current Servo Motors High Performance 5680 and 2100 Series



Permanent Magnet Motors 5680 Series

PERMANENT MAGNET SERVO MOTORS

Peerless Electric 5680 and 2100 Series D.C. Servo Motors provide a wide range of continuous stall torque ratings from 6[illegible] to 19[illegible] inch pounds. Constructed of high coercive [illegible] ferrite permanent magnet field design, these rugged mechanical packages are the ideal selection for precise motion [illegible] control.

FEATURES AND ADVANTAGES

- No Field Supply
- Higher Achievable Peak Efficiency
- Broader Range of Higher Efficiency
- Finished Exterior for Maximum Heat Dissipation
- Feedback Package Mounting Provisions
- Integrally Mounted Low Ripple Tachometer
- Multipolar (6, 8 and 12) for Negligible Low Speed Torque Ripple
- Low Mechanical Time Constants
- Precise Linear Speed—Torque Characteristic
- Low Maintenance—Accessible Design
- Readily Disassembled Without Effective Magnet Flux
- Excellent Performance With DC SCR or Transistor Power Supplies
- Mechanical Options (Brake, Resolvers, Blowers, Etc.)

APPLICATIONS

Numerical Controlled Machine Tools
Antenna Drives
Contouring Systems
Automatic Welding Positioners
Tape Reel Drives
Computers
Military Fire Control Systems
Positioning Tables
Indexing Devices
Steel Mill Processing Lines

Data Sheet
Peerless Electric 5680 Series D.C. Servo Motors

PARAMETER		UNITS	56 FRAME MOTOR DESIGNATIONS			
			DF4-K7707	DF4-K7708	DF4-K7709	DF4-K7710
GENERAL						
Cont. Stall Torque	TENV	Lb. In.	65.0000	65.0000	65.0000	65.0000
at 40C. Amb.	4CFM Shop Air	Lb. In.				
	Blower Cooled	Lb. In.	130.0000	130.0000	130.0000	130.0000
	Air Over Fins	Lb. In.				
Peak Stall Torque	at 25C.	Lb. In.	539.0000	536.0000	528.0000	520.0000
Power at Peak Stall Torque	at 25C.	Kilowatts	4.7400	5.4000	5.0800	5.4000
Mechanical Time Constant	at 25C.	Milliseconds	15.0600	17.3300	16.8000	18.4300
Electrical Time Constant	at 25C.	Milliseconds	4.5000	4.5000	4.5000	4.5000
Motor Constant	at 25C.	Lb. In./Sq. Rt. Watt	7.8300	7.3000	7.4100	7.0800
Visc. Damp. (O. Z Source)	at 25C.	Lb. In./Rad./Sec.	6.9000	6.0200	6.2100	5.6580
Theor. Accel. at Peak Torque		Rad./Sec./Sec.	5168.0000	5142.0000	5065.0000	4986.0000
Torque Ripple		Percent	1.0000	1.0000	1.0000	1.0000
		Cycles/Rev.	109.0000	109.0000	109.0000	109.0000
THERMAL						
Maximum Ambient Temperature		Deg. C	40.0000	40.0000	40.0000	40.0000
Insulation Class			F	F	F	F
Thermal Time Constant		Minutes*	40.0000	40.0000	40.0000	40.0000
TENV Thermal Resistance	Stall	Deg. C/Watt*	0.7600	0.7600	0.7600	0.7600
	Over 600. RPM	Deg. C/Watt*	0.5400	0.5400	0.5400	0.5400
Operating Envelope Curve		DWG No.	K-7775	K-7776	K-7777	K-7778
Duty Cycle Curve		DWG No.	K-7817	K-7817	K-7817	K-7817
WINDING						
Torque Constant	at 25C.	Lb. In./Amp.*	7.5000	5.3600	4.2300	3.1300
Voltage Constant	at 25C.	Volt Sec./Rad.*	0.8530	0.6060	0.4775	0.3540
Arm. Resistance Less Brushes	at 25C.	OHMS*	0.9300	0.5400	0.3250	0.1960
Arm Inductance		Millihenrys*	4.1850	2.4300	1.4600	0.8820
Max. Terminal Voltage		Volts	107.0000	127.0000	125.0000	111.0000
Max. Speed		RPM	1200.0000	2000.0000	2500.0000	3000.0000
Volt. at Peak Torque	at 25C.	Volt	66.4000	54.0000	40.6300	32.5400
Amps. at Peak Torque	at 25C.	Amps.	71.4000	100.0000	125.0000	166.0000
Damping Ratio			0.9150	0.9810	0.9660	1.0100
Undamped Natural Frequency		Rad./Sec.	121.5000	113.2400	115.0200	109.8000
MECHANICAL						
Armature Polar Moment of Inertia		Lb. In. Sec. Sec.*	0.1043	0.1043	0.1043	0.1043
Static Friction Torque		Lb. In.	2.8500	2.8500	2.8500	2.8500
Visc. Damp. (Inf. Z. Source)	at 25C.	Lb. In./Rad./Sec.	0.0082	0.0082	0.0082	0.0082
Motor Weight		Pounds	42.0000	42.0000	42.0000	42.0000
TACHOMETER						
Voltage Gradient		Volts/1000 RPM*	31.5000	31.5000	31.5000	31.5000
		Volt Sec./Rad.*	0.3000	0.3000	0.3000	0.3000
Ripple		Percent	2.0000	2.0000	2.0000	2.0000
		Cycles/Rev.	25.0000	25.0000	25.0000	25.0000
Resistance	at 25C.	OHMS*	64.0000	64.0000	64.0000	64.0000
Inductance		Millihenrys*	70.0000	70.0000	70.0000	70.0000
Minimum Load Resistance		OHMS	6000.0000	6000.0000	6000.0000	6000.0000

*Tolerance Plus or Minus 10 Percent

Refer to outline print
C-114597 for TENV enclosure —
C-114627 for blower cooling —
C-114814 for built-in brake.

AVAILABLE OPTIONS:

Blower Cooled
Shaft Oil Seal
Thermal Protector—Std.
Ultra-Precision Runout
Fail-Safe Brake

WARREN WORKS
1401 W. Market Street
Warren, Ohio 44485
(216) 399-3651

Data Sheet

Peerless Electric 5680 Series D.C. Servo Motors

PARAMETER		UNITS	56 FRAME MOTOR DESIGNATIONS			
			PF4-K7711	PF4-K7712	PF4-K7713	PF4-K7714
GENERAL						
Cont. Stall Torque	TENV	Lb. In.	120.0000	120.0000	120.0000	12[illegible].0000
at 40C. Amb.	4CFM Shop Air	Lb. In.				
	Blower Cooled	Lb. In.	260.0000	260.0000	260.0000	2[illegible].0000
	Air Over Fins	Lb. In.				
Peak Stall Torque	at 25C.	Lb. In.	1050.0000	1032.0000	1030.0000	1034.0000
Power at Peak Stall Torque	at 25C.	Kilowatts	7.6500	7.7000	7.49[illegible]	[illegible].9000
Mechanical Time Constant	at 25C.	Milliseconds	11.6700	12.1700	11.87[illegible]	[illegible].4100
Electrical Time Constant	at 25C.	Milliseconds	4.6000	4.6000	4.60[illegible]	4.6000
Motor Constant	at 25C.	Lb. In./Sq. Rt. Watt	12.0000	11.7500	11.9000	[illegible].6400
Visc. Damp. (O. Z Source)	at 25C.	Lb. In./Rad./Sec.	16.2800	15.6000	16.00[illegible]	[illegible].3100
Theor. Accel. at Peak Torque		Rad./Sec./Sec.	5527.0000	5429.0000	5423.00[illegible]	544[illegible].0000
Torque Ripple		Percent	1.0000	1.0000	1.00[illegible]	[illegible].0000
		Cycles/Rev.	108.0000	108.0000	108.00[illegible]	[illegible].0000
THERMAL						
Maximum Ambient Temperature		Deg. C	40.0000	40.0000	40.0000	4[illegible].0000
Insulation Class			F	F	F	F
Thermal Time Constant		Minutes*	60.0000	60.0000	60.00[illegible]	6[illegible].0000
TENV Thermal Resistance	Stall	Deg. C/Watt*	0.5900	0.5900	0.59[illegible]	[illegible].5900
	Over 600. RPM	Deg. C/Watt*	0.4400	0.4400	0.44[illegible]	[illegible].4400
Operating Envelope Curve		DWG No.	K-7779	K-7780	K-77[illegible]	K-778[illegible]
Duty Cycle Curve		DWG No.	K-7818	K-7818	K-78[illegible]	K-7818
WINDING						
Torque Constant	at 25C.	Lb. In./Amp.*	7.2900	5.6400	4.09[illegible]	[illegible]300
Voltage Constant	at 25C.	Volt/Sec./Rad.*	0.8240	0.6370	0.46[illegible]	[illegible]480
Arm. Resistance Less Brushes	at 25C.	OHMS*	0.3690	0.2300	0.11[illegible]	[illegible]700
Arm. Inductance		Millihenrys*	1.7000	1.0580	0.54[illegible]	[illegible].3220
Max. Terminal Voltage		Volts	103.5000	133.4000	121.00[illegible]	[illegible]
Max. Speed		RPM	1200.0000	2000.0000	2500.00[illegible]	300[illegible].0000
Volt. at Peak Torque	at 25C.	Volts	53.1000	42.0900	29.74[illegible]	[illegible]200
Amps. at Peak Torque	at 25C.	Amps	144.0000	183.0000	252.00[illegible]	3[illegible].0000
Damping Ratio			0.7960	0.8130	0.80[illegible]	[illegible].8210
Undamped Natural Frequency		Rad./Sec.	136.5000	133.6600	135.34[illegible]	1[illegible].3600
MECHANICAL						
Armature Polar Moment of Inertia		Lb. In. Sec. Sec.*	0.1900	0.1900	0.19[illegible]	[illegible].1900
Static Friction Torque		Lb. In.	4.7000	5.5000	5.10[illegible]	5.[illegible]000
Visc. Damp. (Inf. Z. Source)	at 25C.	Lb. In./Rad./Sec.	0.0850	0.0580	0.05[illegible]	[illegible]780
Motor Weight		Pounds	59.0000	59.0000	59.00[illegible]	5[illegible].0000
TACHOMETER						
Voltage Gradient		Volts/1000 RPM*	31.5000	31.5000	31.50[illegible]	3[illegible]000
		Volts/Sec./Rad.*	0.3000	0.3000	0.30[illegible]	[illegible]000
Ripple		Percent	2.0000	2.0000	2.00[illegible]	[illegible]000
		Cycles/Rev.	25.0000	25.0000	25.00[illegible]	2[illegible]000
Resistance	at 25C.	OHMS*	64.0000	64.0000	64.00[illegible]	6[illegible]000
Inductance		Millihenrys*	70.0000	70.0000	70.00[illegible]	[illegible]000
Minimum Load Resistance		OHMS	6000.0000	6000.0000	6000.00[illegible]	60[illegible]000

*Tolerance Plus or Minus [illegible] Percent

Refer to outline print
C-14597 for TENV enclosure —
C-14627 for blower cooling —
C-14615 for built-in brake

AVAILABLE OPTIONS:

Blower Cooled
Shaft Oil Seal
Thermal Protector—Std.
Ultra-Precision Runout
Fail-Safe Brake

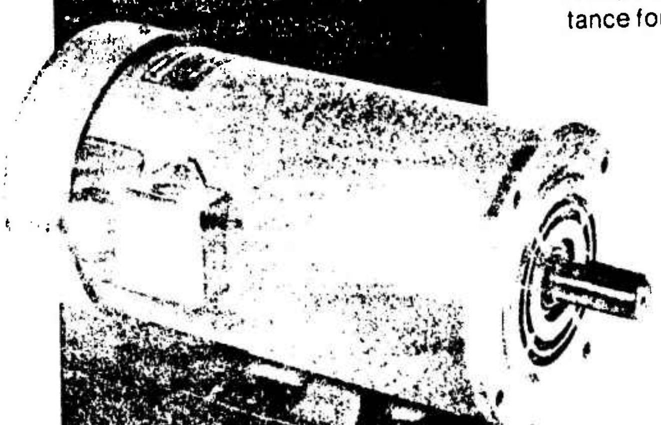
WARREN WORKS
1401 W. Market Street
Warren, Ohio 444[illegible]
(216) 399-[illegible]

MODEL

SR53

SCR RATED

Permanent-Magnet-Field DC Motors designed for use with full-wave SCR controls.



3/4 to 2 HP

DESIGN RANGE:

Horsepower—3/4 to 2
DC Voltage—90V DC and 180V DC
Standard speed—1750 RPM
(special speeds from 500 to 3600 RPM)
Full torque over entire speed range.

DESIGN FEATURES:

Smaller motor size and greater efficiency than shunt field DC motor of same horsepower • Precision-machined brush guide with generous heat-radiating surfaces, plus constant-pressure negator spring, assure superior brush life • Skewed magnetic field smooths low-speed operation • Class "H" insulation (200°C hotspot) • Two-pole construction gives higher inductance for improved form factor • Typical regulation 10%.

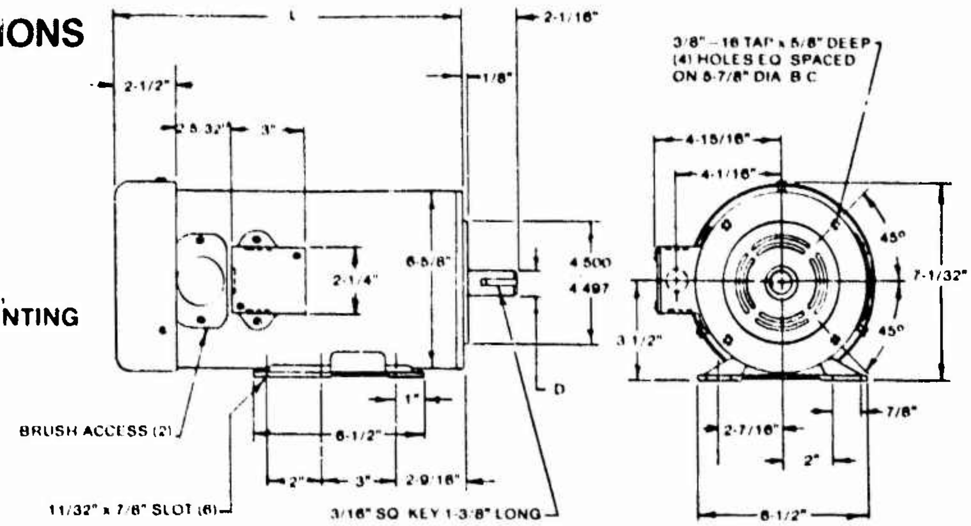
Type of Construction: TEFC (open drip-proof model gives economical package at 2 HP).
Brush Design: Generous brush contact area (5/16" x 1-1/4"). Negator spring.
Direction of Operation: Can be run in either direction by merely reversing terminal polarity.
Current Limiting: Required.
Junction Box Location: 10 cu. in. junction box for easy wiring.
Equipped with welded mounting feet.

DESIGN OPTIONS:

- Rear Shaft Extension
- Overheat Thermostat
- Shaft Variations
- Precision Balance
- Shaft Seal
- Integral Tachometer
- End Bell Variations

SPECIFICATIONS

. ODEL SR53 TEFC,
56BC or 45BC MOUNTING



MOTOR PART NUMBER		RATED Volt	HP	RPM	Amp	Lb. In.	Allowable Peak Amp	CONSTANTS R_A	I	mh	DIMENSIONS L In.*	D In	NEMA*	WT. LBS.
SR5320-2292	TEFC	90	3/4	1750	7.1	27	62	1.10	14.3	6.4	11⅝	⅝	56	32
SR5320-[illegible]	TEFC	180	3/4	1750	3.6	27	31	4.30	14.3	25.6	11⅝	⅝	56	32
SR[illegible]	TEFC	90	[illegible]	1750	[illegible]	36	76	.73	16.0	5.1	11⅝	⅝	56	34
[illegible]	TEFC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	2.95	16.0	20.3	[illegible]	⅝	56	34
[illegible]	[illegible]	[illegible]	[illegible]	1750	[illegible]	[illegible]	76	1.63	23.0	40.1	[illegible]	⅞†	145T	61
SR5364-1855	ODP	180	2	1750	9.5	72	100	.95	28.5	8.0	16[illegible]	⅞†	145T	85

†Shaft length 2 1/8

Continuous duty

***Mounting Suffixes:**

56C NEMA 56C Face (5/8" Dia. Shaft)
56B NEMA 56 and 145 Base
56BC NEMA 56C Face and 56 - 145 Base
45C NEMA 145TC Face (7/8" Dia. Shaft)
45BC NEMA 145TC Face and 56 - 145 Base

Definitions:

TEFC – Totally Enclosed, Fan Cooled
ODP Open, Drip Proof
mh millihenries inductance
I lb-in² inertia
R_A – ohms armature resistance

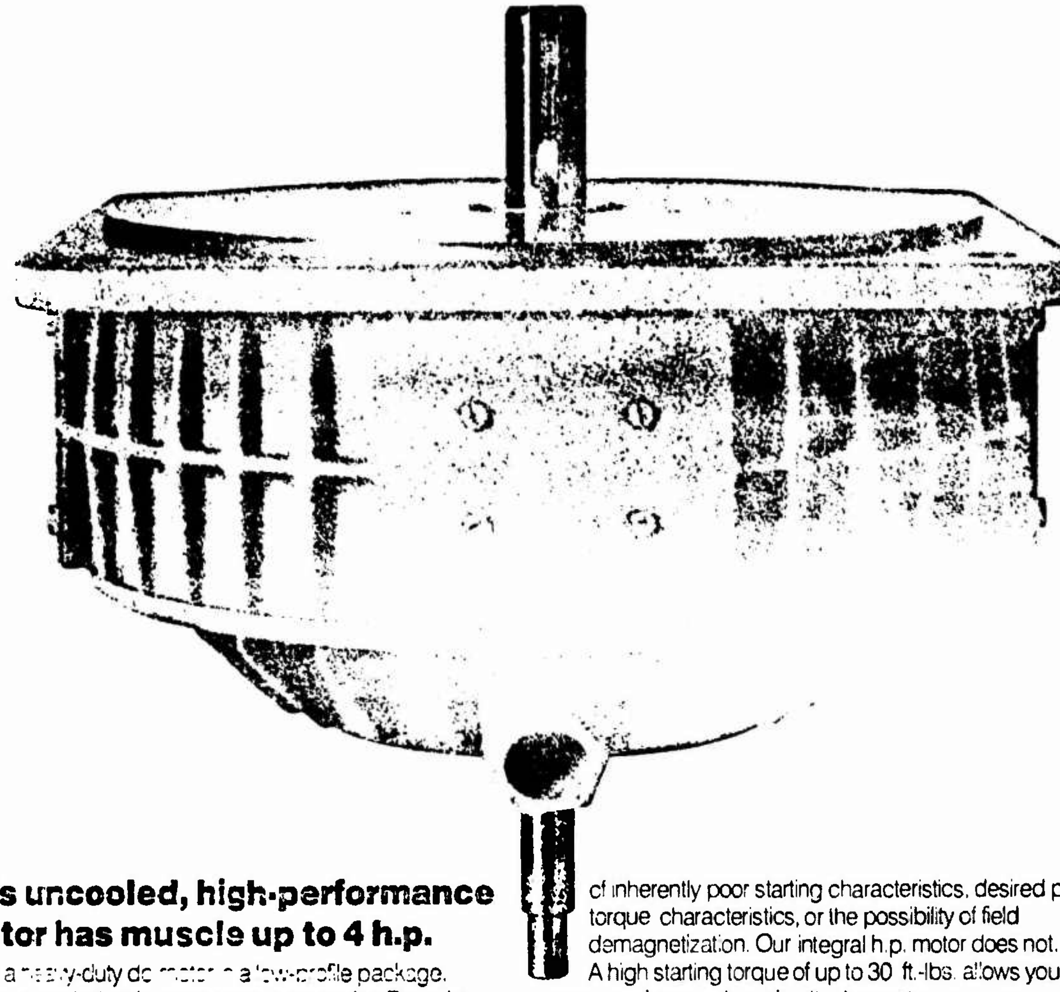
MANUFACTURED BY

APPLIED MOTORS OPERATION
MICRO SWITCH
A DIVISION OF HONEYWELL

4801 BOEING DRIVE • P.O. BOX 106
ROCKFORD, ILLINOIS 61105

REPRESENTED BY

Integral h.p. motors with the Pancake armature.



This uncooled, high-performance dc motor has muscle up to 4 h.p.

Here's a heavy-duty dc motor in a low-profile package. Inside that rugged industrial case there is a genuine Pancake armature and strong Alnico magnets that just don't demagnetize.

With greatly reduced motor weight, our integral h.p. motor has advantages wherever high torque response [illegible] variable speed or position control is required. For example, in packaging and process control equipment, web and conveyor systems and material handling equipment.

A faster response.

Instead of the conventional heavy, cylindrical iron core found in ordinary ac and dc motors, this integral h.p. motor has a unique Pancake armature.

Because there is no iron in this [illegible] Pancake armature, rotor [illegible] extremely low and inductance is virtually zero. The resulting high torque-to-inertia ratio gives a very fast response. For example, from 0 to 1575 rpm in [illegible] for the 4 h.p. motor.

A more exact rating.

Many conventional motors have to be overrated because of inherently poor starting characteristics, desired peak torque characteristics, or the possibility of field demagnetization. Our integral h.p. motor does not.

A high starting torque of up to 30 ft.-lbs. allows you to save space and money by using the lowest horsepower necessary to obtain the peak output you need.

A longer life.

This integral h.p. motor is designed and built to be rugged, reliable and long-lasting. For example, brushes commutate directly on the armature. With a large number of flat commutator segments and negligible inductance, commutation arcing is eliminated, even at high current levels. And there is no cogging at any speed.

As a result, brush-life is longer (up to 10,000 hours at rated operating levels).

Our integral h.p. motor comes in four basic sizes: 4 h.p. at 2500 rpm, 120 vdc, 2.3 h.p. at 3000 rpm, 168 vdc; 1.3 h.p. at 3000 rpm, 164 vdc; and 1.3 h.p. at 3000 rpm, 90 vdc. All can be operated at higher ratings with air cooling (easily accomplished because of the motor configuration).

A better buy.

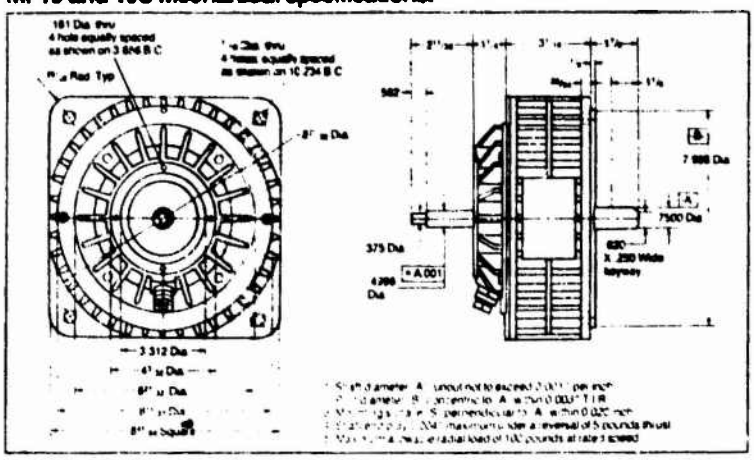
With its faster response, more exact rating and longer life, this integral h.p. motor is highly competitive in most applications. And when you consider simplification and improved performance of driven equipment, it is your best buy.

Ratings and constants for the integral h.p. Pancake

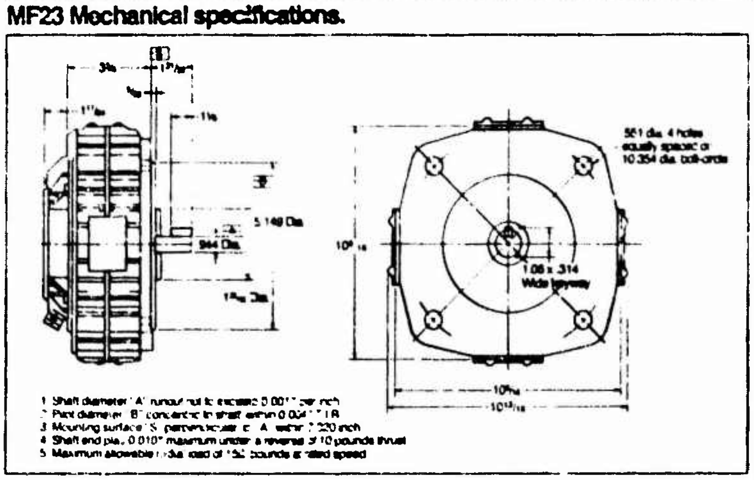
Type	Continuous Torque* (Oz-In)	Rated Speed* (RPM)	Power Out (HP)	Rated Current (Amps)	Voltage (VDC)	Pulse Torque (Oz-In)	Power Rate* (KW/sec)	Continuous Stall Current (Amps)	Term. Resistance (Ohms @25°C)	Torque Constant (Oz-In/amp)	Emf Constant (V/KRPM)	Motor Inertia (Oz-In Sec²)	Mechanical Time* Constant (msec)	Friction (Oz-In)	Dimensions Length (Inch)	Dimensions Diameter (Inch)
MF19	450	3000	1.3	12.0	90	4800	900	14.0	0.56	37.0	27.3	0.18	11.0	20.0	4.31	8.34
MF19S	450	3000	1.3	7.2	164	3450	500	8.0	1.40	69.0	51.0	0.17	9.0	14.2	4.35	9.02
MF23	900	3000	2.7	13.6	168	7800	1200	19.0	0.70	70.4	49.7	0.36	10.0	14.2	5.04	10.80
MF26	1500	2500	3.9	25.7	120	6200	470	26.0	0.28	62.0	45.0	0.58	6.0	25.0	5.45	11.92

*See notes on page 9. All motors are available with tachometer

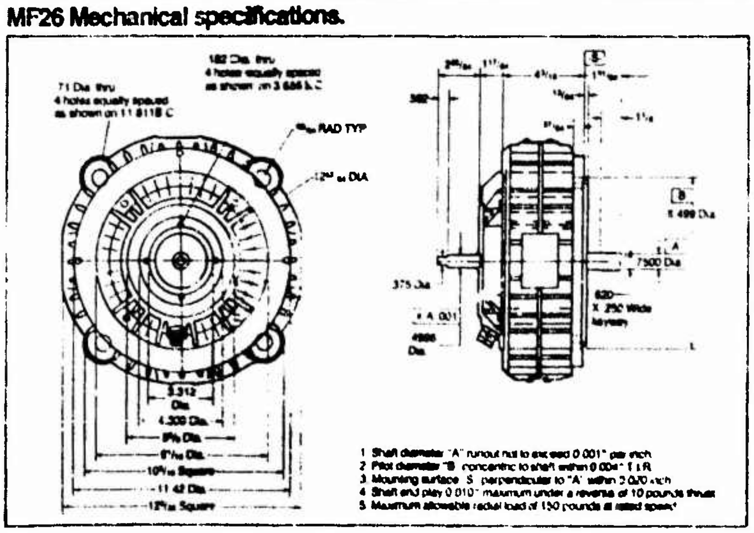
MF19 and 19S Mechanical specifications.



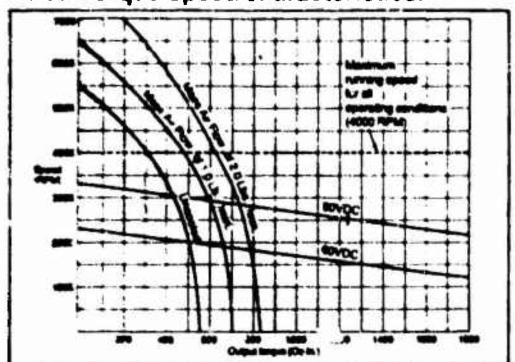
MF23 Mechanical specifications.



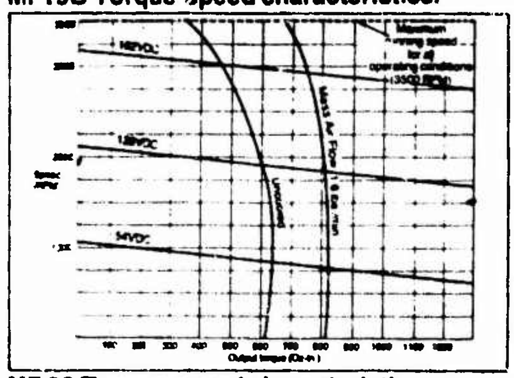
MF26 Mechanical specifications.



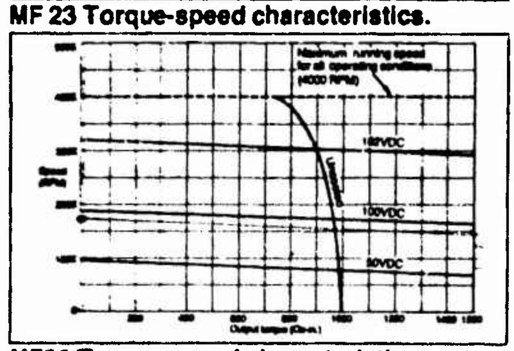
MF19 Torque-speed characteristics.



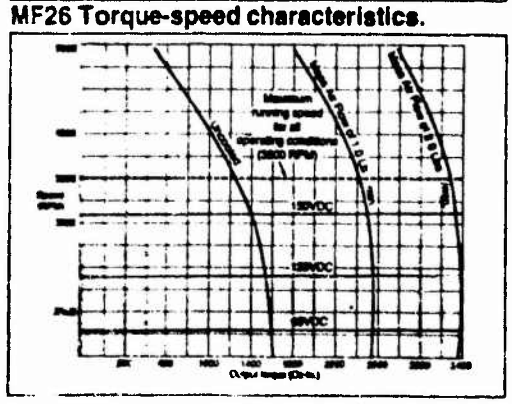
MF19S Torque-speed characteristics.



MF 23 Torque-speed characteristics.



MF26 Torque-speed characteristics.

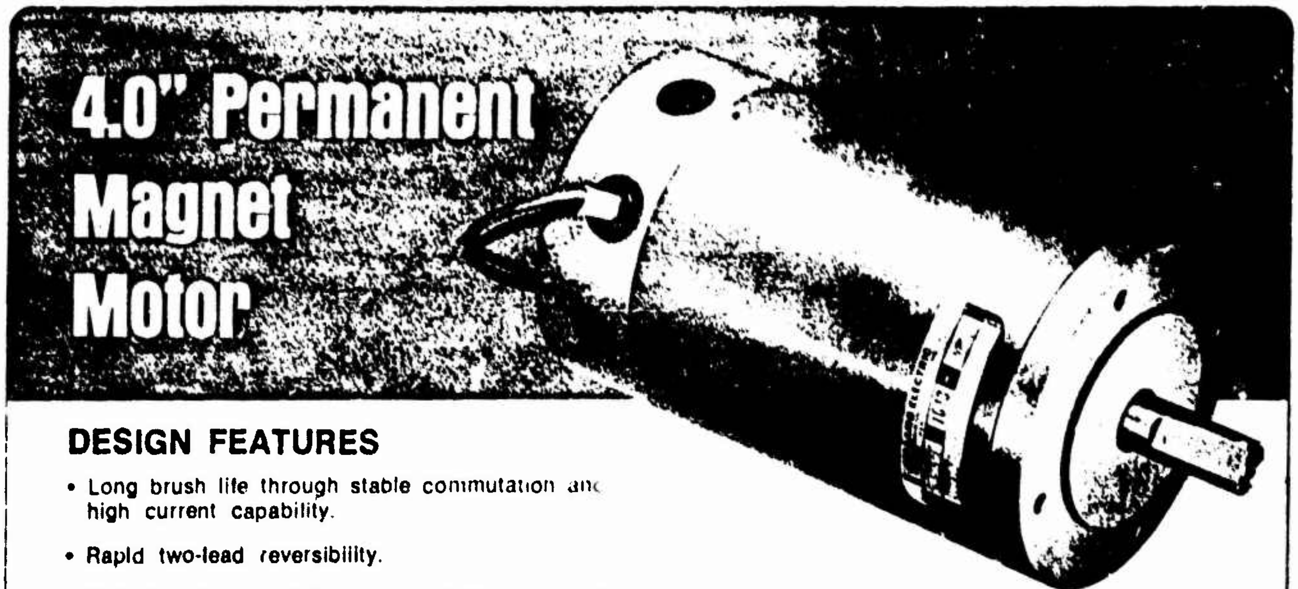


bulletin

AMETEK

LAMB AC, DC MOTORS

1-MP400-001
January 5, 1976*



DESIGN FEATURES

- Long brush life through stable commutation and high current capability.
- Rapid two-lead reversibility.
- High torque in small frame size saves space and weight.
- High efficiency results in low current draw.
- Class F insulation
- DC and rectified AC excitation

DESCRIPTION

The Lamb Electric high performance permanent magnet motor line is especially designed to meet the demanding requirements of the computer peripheral equipment market. In order to produce an economical design of superior performance and construction, this motor reflects the high volume production know-how and cost reducing techniques of Lamb Electric.

This 4" diameter unit is available in standard 5", 6" and 7" lengths with stainless steel shafts. Meets torque requirements from 100 oz-in to 1500 oz-in and speeds to 5800 r.p.m. Double shielded, permanently lubricated precision bearings are pre-loaded for minimum end play (does not exceed .002" with 10 lb. thrust load applied in either direction).

These motors use the latest ceramic permanent magnets, the newest methods of armature insulation, and proven design construction to give the rapid and repeatable acceleration rates required in closed loop electrical systems.

APPLICATIONS

Designed specifically for the computer peripheral market, these high performance motors are equally well suited for other data processing equipment, copying and reproduction equipment, machine tools and similar applications. Simple, compact construction provides lightweight, longlife motors. These motors are U.L. Component Recognized under guide OBJY2 and PRGY2.

ECONOMIES

Lamb permanent magnet motors are most economical in applications where a repeatable straight-line speed/torque curve and high efficiency are a design requirement. The cost reducing, value increasing high volume production capabilities of Lamb Electric lend themselves to mid and high range production. Attractive pricing, plus the cost savings derived from engineering assistance, prompt delivery and service, combine to make these motors an economical power package. The line features a number of standard designs, and for low volume requirements, some stock units are maintained in inventory. For the latest stock listing, consult with the Lamb sales office.

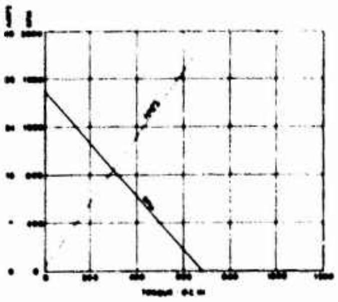
*Supersedes Issue of October 1, 1974.

DIMENSIONS

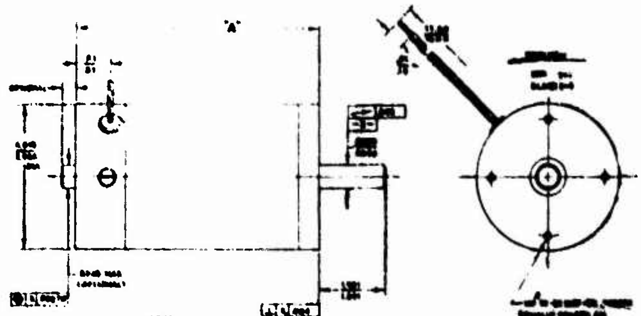
PERFORMANCE EXAMPLE @ 24V DC

STALL TORQUE	T_s	OZ. IN.	680
STALL CURRENT	I_s	AMPS	37.5
NO LOAD SPEED	NL	RPM	1470
NO LOAD CURRENT	I_{NL}	AMPS	70

FIG. 1



FACE MOUNT

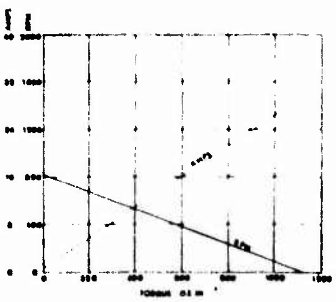


"A"
(E-4965-1) 5" Max.
(E-4965-2) 6" Max.
(E-4965-3) 7" Max.

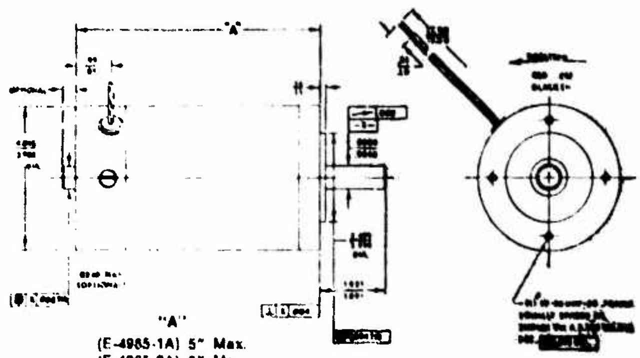
PERFORMANCE EXAMPLE @ 24V DC

STALL TORQUE	T_s	OZ. IN.	1150
STALL CURRENT	I_s	AMPS	29.5
NO LOAD SPEED	NL	RPM	820
NO LOAD CURRENT	I_{NL}	AMPS	60

FIG. 2



PILOT MOUNT

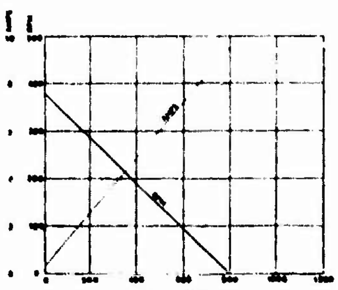


"A"
(E-4965-1A) 5" Max.
(E-4965-2A) 6" Max.
(E-4965-3A) 7" Max.

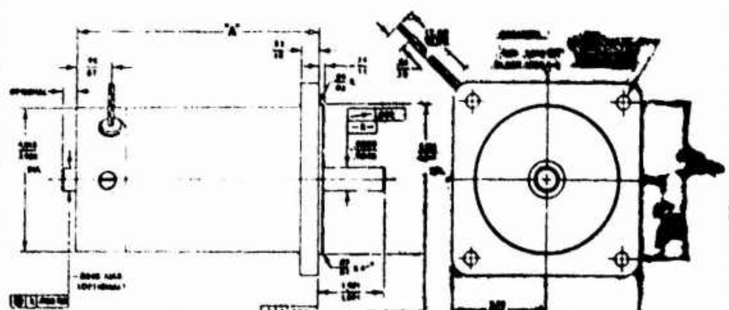
PERFORMANCE EXAMPLE @ 24V DC

STALL TORQUE	T_s	OZ. IN.	800
STALL CURRENT	I_s	AMPS	9.6
NO LOAD SPEED	NL	RPM	385
NO LOAD CURRENT	I_{NL}	AMPS	.40

FIG. 3



FLANGE MOUNT



"A"
(E-4965-1B) 5" Max.
(E-4965-2B) 6" Max.
(E-4965-3B) 7" Max.

PERFORMANCE CHARACTERISTICS (4.0" Permanent Magnet Motor @ 25°C)

5 inch Length

ITEM	CONSTANT	UNITS OF MEAS.	5" LENGTH MODEL E-4965-1, 1A, 1B								
VOLTAGE CONSTANT	K_b	VOLTS/KRPM	10.1	12.6	15.1	20.1	25.2	32.7	40.3	50.4	63.0
VOLTAGE CONSTANT	K_v	VOLTS SEC/RADIAN	.096	.120	.144	.192	.240	.312	.384	.480	.600
TORQUE CONSTANT	K_t	OZ-IN/AMP	[illegible]	17.0	20.4	27.2	34.0	44.2	54.4	68.0	85.0
TERMINAL RESISTANCE	R_t	OHMS	.30	.45	[illegible]	[illegible]	1.69	[illegible]	4.26	6.71	10.61
INDUCTANCE	L_a	MILLI-HENRIES	[illegible]	[illegible]	[illegible]	[illegible]	6.048	9.828	[illegible]	24.156	38.106
RATED CURRENT	I_r	AMPERES	[illegible]	9.09	[illegible]	[illegible]	[illegible]	[illegible]	2.99	2.38	1.89
MAXIMUM CURRENT	I_m	AMPERES	80	64	53.3	40	32	24.6	20	16	12.8
INDUCTIVE TIME CONSTANT	T_a	MILLI-SECONDS	[illegible]	[illegible]	3.6	3.6	3.6	3.6	3.6	3.6	3.6
MECHANICAL TIME CONSTANT	T_m	MILLI-SECONDS	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
VISCOUS DAMPNG CONSTANT	K_d	OZ-IN/RADIAN/SEC	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
MOTOR TORQUE CONSTANT	K_m	OZ-IN/VOLT	45.33	[illegible]	31.38	25.66	20.24	16.19	[illegible]	10.13	8.01
MOTOR—GENERAL											
ARMATURE INERTIA	J_m	OZ-IN-SEC²	.09								
STATIC FRICTION TORQUE	T_f	OZ-IN	8.15 (Brush friction plus cogging)								
ROTATIONAL LOSS TORQUE	T_r	OZ-IN/KRPM	5								
THERMAL RESISTANCE	θ_t	°C/WATT	2.2 (Winding to ambient)								
WEIGHT		LBS	6.8								

6 inch Length

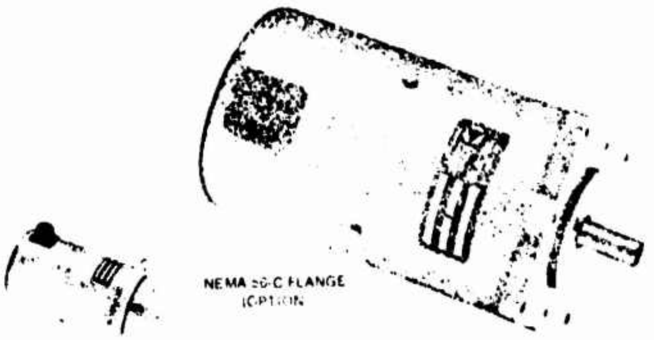
ITEM	CONSTANT	UNITS OF MEAS.	6" LENGTH MODEL E-4965-2, 2A, 2B								
VOLTAGE CONSTANT	K_b	VOLTS/KRPM	17.8	22.2	26.7	35.6	44.4	57.8	[illegible]	88.9	111.1
VOLTAGE CONSTANT	K_v	VOLTS SEC/RADIAN	[illegible]	.21	.26	.34	.43	.55	.68	.85	1.06
TORQUE CONSTANT	K_t	OZ-IN/AMP	24.0	30.0	36.0	48.0	60.0	78.0	96.0	120.0	150.0
TERMINAL RESISTANCE	R_t	OHMS	.38	.58	.86	1.40	[illegible]	3.61	5.62	8.86	14.01
INDUCTANCE	L_a	MILLI-HENRIES	[illegible]	[illegible]	4.558	[illegible]	[illegible]	[illegible]	[illegible]	46.958	74.253
RATED CURRENT	I_r	AMPERES	[illegible]	[illegible]	[illegible]	[illegible]	4.85	3.79	3.04	2.42	1.93
MAXIMUM CURRENT	I_m	AMPERES	80	64	53.3	40	32	24.6	20	16	12.8
INDUCTIVE TIME CONSTANT	T_e	MILLI-SECONDS	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
MECHANICAL TIME CONSTANT	T_m	MILLI-SECONDS	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
VISCOUS DAMPNG CONSTANT	K_d	OZ-IN/RADIAN/SEC	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
MOTOR TORQUE CONSTANT	K_m	OZ-IN/VOLT	63.16	[illegible]	41.86	[illegible]	[illegible]	[illegible]	17.08	13.54	10.71
MOTOR—GENERAL											
ARMATURE INERTIA	J_m	OZ-IN-SEC²	.14								
STATIC FRICTION TORQUE	T_f	OZ-IN	8.15 (Brush friction plus cogging)								
ROTATIONAL LOSS TORQUE	T_r	OZ-IN/KRPM	[illegible]								
THERMAL RESISTANCE	θ_t	°C/WATT	1.6 (Winding to ambient)								
WEIGHT		LBS	9.25								

7 inch Length

ITEM	CONSTANT	UNITS OF MEAS.	7" LENGTH MODEL E-4965-3, 3A, 3B								
VOLTAGE CONSTANT	K_b	VOLTS/KRPM	24.5	30.7	36.8	49.0	61.3	79.7	98.1	122.6	153.3
VOLTAGE CONSTANT	K_v	VOLTS SEC/RADIAN	.234	.293	.351	.468	.585	.761	.936	1.170	1.463
TORQUE CONSTANT	K_t	OZ-IN/AMP	33.1	41.4	49.7	66.2	82.8	107.6	132.4	165.5	206.9
TERMINAL RESISTANCE	R_t	OHMS	.48	.70	1.05	1.70	2.69	4.38	6.83	10.76	17.02
INDUCTANCE	L_a	MILLI-HENRIES	3.120	[illegible]	6.825	11.050	17.485	28.470	44.395	69.940	110.630
RATED CURRENT	I_r	AMPERES	11.55	9.56	7.81	6.14	4.88	3.82	3.06	2.44	1.94
MAXIMUM CURRENT	I_m	AMPERES	80	64	53.3	40	32	24.6	20	16	12.8
INDUCTIVE TIME CONSTANT	T_a	MILLI-SECONDS	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
MECHANICAL TIME CONSTANT	T_m	MILLI-SECONDS	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
VISCOUS DAMPNG CONSTANT	K_d	OZ-IN/RADIAN/SEC	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
MOTOR TORQUE CONSTANT	K_m	OZ-IN/VOLT	68.96	59.14	47.33	38.94	30.78	24.57	19.39	15.38	12.16
MOTOR—GENERAL											
ARMATURE INERTIA	J_m	OZ-IN-SEC²	.20								
STATIC FRICTION TORQUE	T_f	OZ-IN	8.15 (Brush friction plus cogging)								
ROTATIONAL LOSS TORQUE	T_r	OZ-IN/KRPM	9								
THERMAL RESISTANCE	θ_t	°C/WATT	1.3 (Winding to ambient)								
WEIGHT		LBS	11.2								

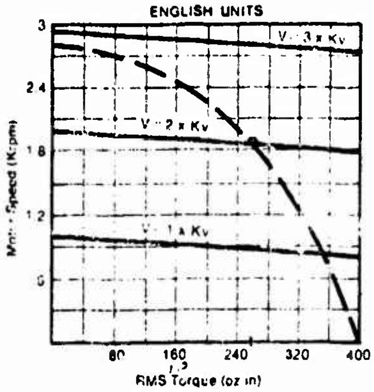
SNAPPER SERIES
MOTORS AND MOTOR-TACHS

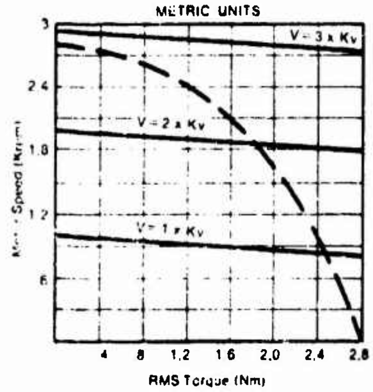
FRAME SIZE 5130

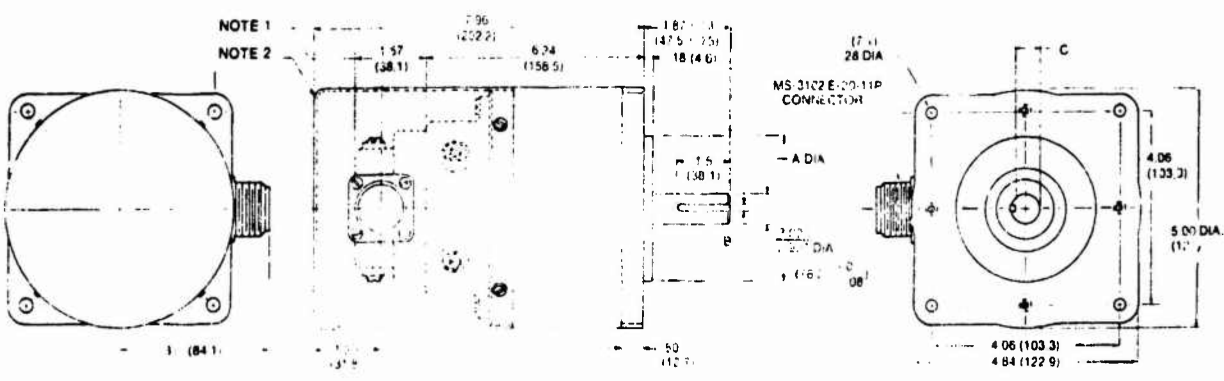


The SNAPPER is a high performance permanent magnet field DC servo motor for use in both direct drive or geared servo systems. It is capable of high speed, as well as plugging and operation at stall. The 5130 frame is rated for a continuous output power of ½ HP without forced cooling, while providing an acceleration of 10,000 radians per second squared (95 RPM per millisecond). This performance is suitable for computer peripheral devices and machine tool controls. See reverse side for detailed performance specifications.

— — — The area under the curve represents the continuous duty operating zone (TENV) — — —







DIMENSIONS IN MILLIMETERS

NOTES

1. DIMENSION APPLIES TO TACHOMETER OPTION. MOTOR ONLY VERSION WILL HAVE A REAR SHAFT EXTENSION $\frac{.500}{.499}$ $\left(\frac{12.7}{12.6}\right)$ x 1.19 (30.23)
2. SEALED UNIT (OPTION) INCLUDES SEALED CAN, SEALED FRONT BEARING & CONNECTOR

SYSTEM	MOTOR ONLY PART NO	MOTOR & TACHOMETER PART NO	A	B	C
ENGLISH	MH 5130-001-*	MT 5130-002-* **	$\frac{.625}{.624}$	.187 $^{+.002}_{0}$	.517 $^{+0}_{-.01}$
METRIC	MH 5130-703-*	MT 5130-704-* **	15 $^{+0}_{-.03}$	5 $^{+.05}_{0}$	12 $^{+0}_{-.25}$

* Letter denoting winding specifications
** Letter denotes tach gradient

FOR SPECIAL SHAFT AND MOUNTING CONFIGURATION, CONSULT FACTORY.

Polarity markings: when red motor teminal is plus, rotation is CCW facing output shaft end, and red tachometer terminal is plus.

Specifications @ 25°C

FRAME SIZE 5130

SYM	PARAMETER	UNITS	A	B	C	D	E	F	G	H
			MOTOR WINDING OPTIONS							
K_T	Torque sensitivity ± 10%	English - oz in/amp	29.0	37.3	49.8	62.2	74.7	99.6	124	149
		Metric - Nm/amp	.205	.263	.352	.439	.527	.703	.876	1,052
R_M	Resistance of armature, (note 1) ± 15%	ohms	0.32	0.52	0.85	1.33	2.10	3.5	5.30	8.4
	Amps at peak torque (note 2)	amps	41.4	32.2	24.1	19.3	16.1	12.0	9.7	8.1
	Volts at peak torque, stall	volts	14	18	21	27	34	47	52	68
K_V	Volts back EMF	volts/1000 rpm	21.5	27.6	36.9	46.0	55.3	73.7	91.8	110.3

PARAMETER	UNITS - ENGLISH		UNITS - METRIC	
Torque, (peak)	oz in	1,200	Nm	8.5
Torque (continuous)	oz in	400	Nm	2.8
Viscous friction constant	oz in/1000 rpm	12	Nm/1000 rpm	.085
Static friction torque	oz in	15	Nm	.106
Cogging torque at zero excitation	oz in	5	Nm	.035
Moment of inertia (motor only)	oz in sec²	0.12	Kg m²	.847 x 10⁻³
Acceleration, peak (motor only)	rad/sec²	10,000	rad/sec²	10 000
Rated power	HP	1/2	HP	1/2
Time constant, mechanical (motor)	millisec	6.4	millisec	6.4
Time constant, electrical	millisec	2.0	millisec	2.0
Thermal resistance mounted (note 3)	deg C/watt	1.3	deg C/watt	1.3
Thermal time constant	minutes	30	minutes	30
Armature temp, max allowable	deg C	155	deg C	155
Motor/tach torsional res freq	hertz	4,000	hertz	4 000
Weight, motor only	lbs	19	Kg	8.6
Weight, motor + tach	lbs	20	Kg	9.2

TACHOMETER (OPTION)		E	F	G
		WINDING OPTIONS		
Output Voltage (volts/1000 rpm)		3	7	15
Armature DC Resistance (ohms)		45	100	450
Voltage Ripple (max dev from avg with 10 KHz filter)		± 1.5%	± 1.5%	± 1.5%
Ripple Frequency (cycles/revolution)		21	21	21
Output Voltage Linearity (referenced to 3600 rpm)		± 0.05%	± 0.05%	± 0.05%
Temperature Coefficient (nominal)		−0.016%/°C	−0.016%/°C	−0.016%/°C
Inertia	English oz in sec²	.001	.001	.001
	Metric Kgm²	7,06 x 10⁻⁶	7,06 x 10⁻⁶	7,06 x 10⁻⁶

Notes: 1. Add .2 ohms for terminal resistance
2. Max. current to avoid demagnetization
3. English: 10" x 10" x ¼" aluminum plate Metric: 25.4cm x 25.4cm x .635cm aluminum plate

MOTOR RATINGS AND CONSTRUCTION FEATURES

Rated Brush Life (Minimum): 8,000 hours @ 1 Krpm.
Maximum Radial Shaft Loading: 70 lbs. (32 Kg) @ .5 in. (13mm) from front bearing, continuous for a minimum 10,000 hours.
Winding insulation: Class F.
ABEC Class 1 Ball Bearings.

Specifications Subject to Change Without Notice

TORQUE SYSTEMS INCORPORATED
AN EG&G ROTRON COMPANY

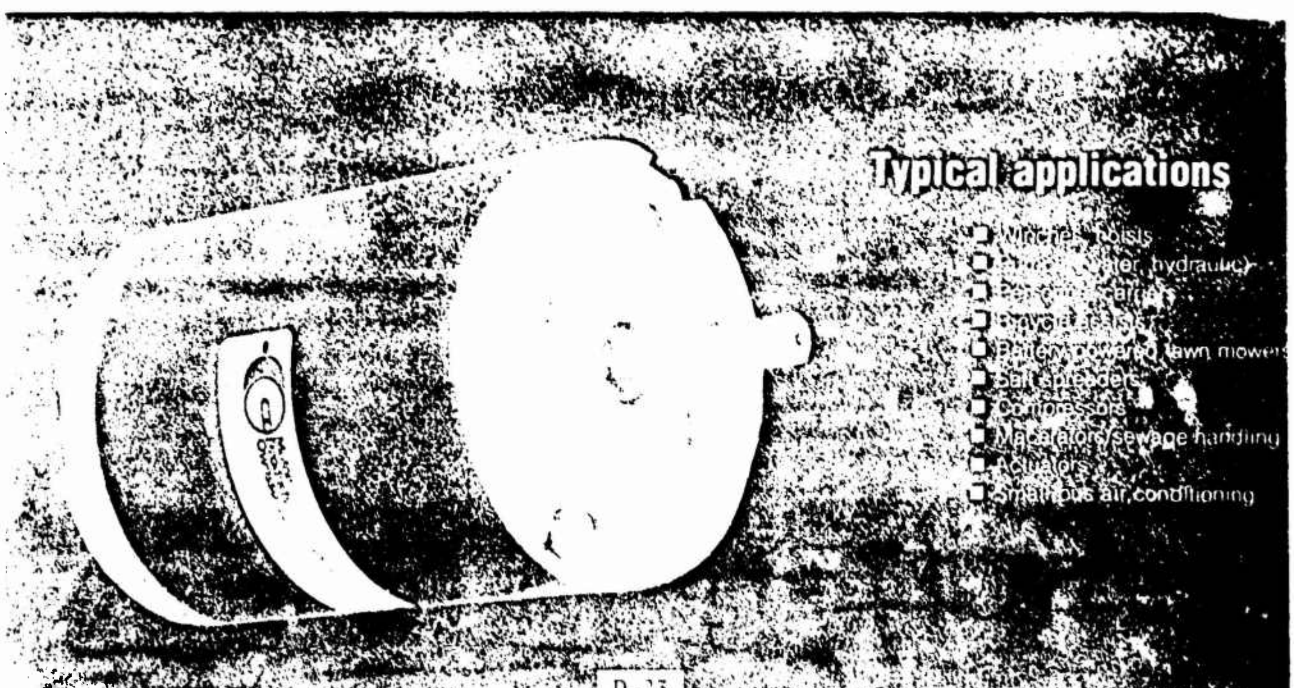
P.O. Box 588
225 Crescent Street
Waltham, Massachusetts 02154
Tel. (617)891-0230 Telex 92-3424

THE BRUTE!

And BRUTE POWER is what you will get with this latest addition to our permanent magnet motor line. Type PR Motors power those heavy duty applications requiring high efficiency to extend battery life. Rugged die cast end frames incorporate ball or sleeve bearings to handle those difficult loading applications.

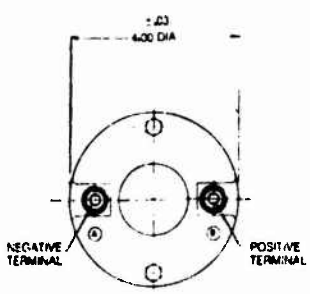
Type PR Motors are available in sizes of 1/5 to 1/2 hp., with intermittent duty applications exceeding 1 hp. Mounting arrangements will be provided to adapt to your application. Compare cost for performance, THE BRUTE could be the answer to your present or future product applications.

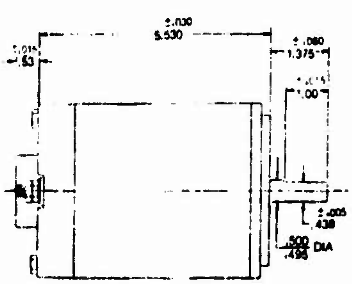
Redmond type PR permanent-magnet D.C. motor



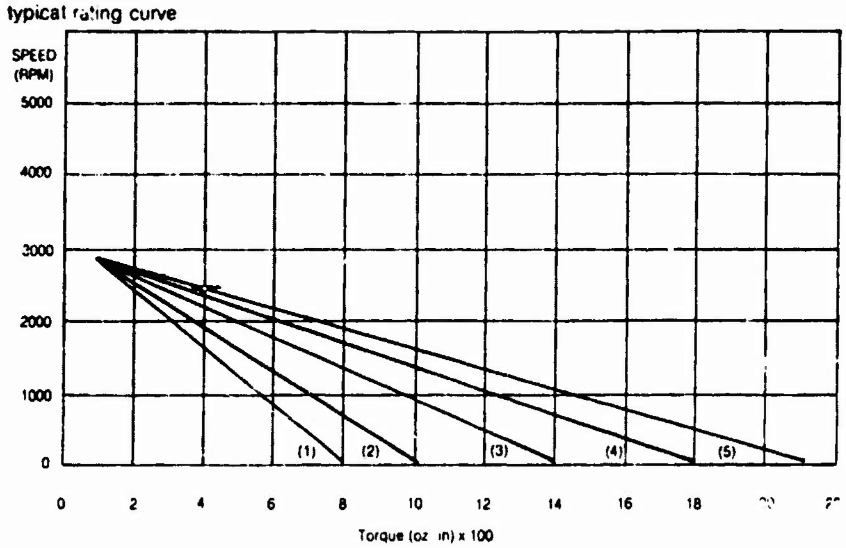
Redmond type PR permanent-magnet D.C. motor

Enclosure	Totally enclosed
Volts	12, 24, 36, 48 volt D C (others available)
Electrical Connection	1/4-20 insulated studs
Bearing System	Sleeve and ball or two ball bearings (double shielded and high temp. grease)
Rotation	CW or CCW
End Frames	Die cast zinc
Finish	Black painted, corrosion-resistant shell
Mounting	Per customer request





Nominal performance
typical rating curve



Model	Curve No.	Length A (case length)	Weight
PR4600Q	1	5.03"	8 lbs. 6 oz.
PR4800Q	2	5.53"	9 lbs. 2 oz.
PR4P00Q	3	6.03"	9 lbs. 14 oz.
PR4R00Q	4	6.53"	10 lbs. 10 oz.
PR4Y00Q	5	7.03"	11 lbs. 6 oz.

Redmond engineers will be happy to work with you to adapt the motor that is just right for your needs.

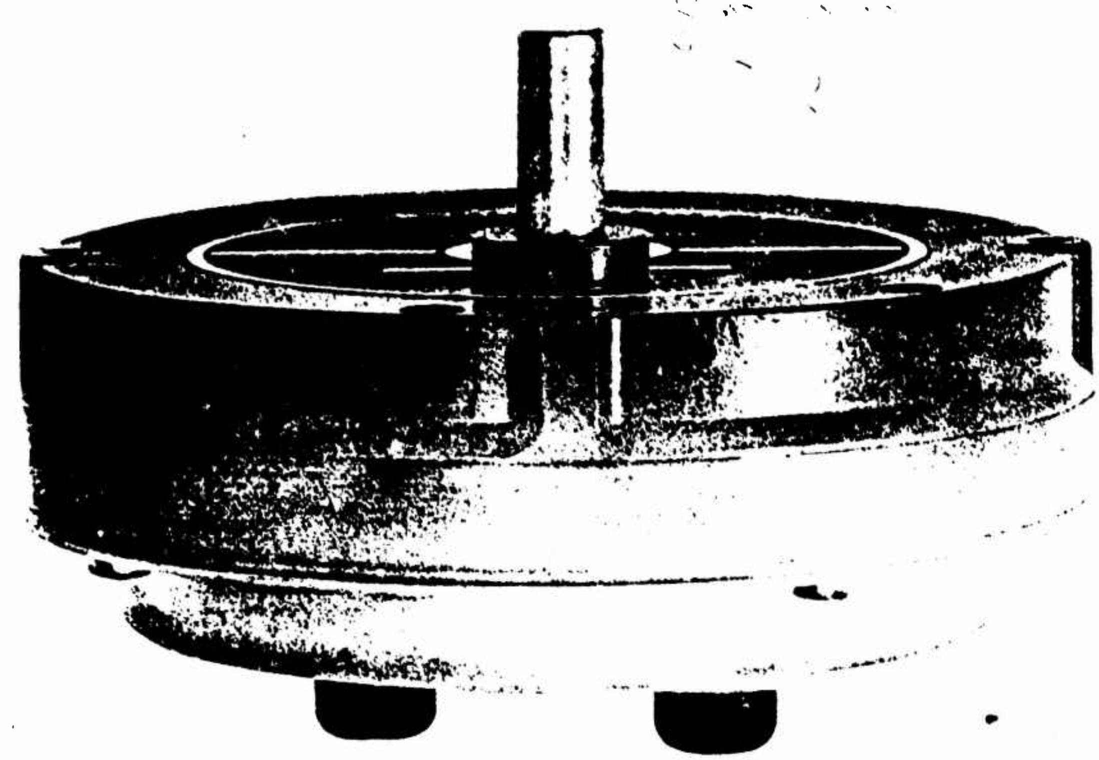
1 to 100
$100 each

65% efficiency

Motor Products Owosso Corporation
201 S. Delaney Road
Owosso, Michigan 48867
(517) 725-5151

MANUFACTURERS OF Redmond MOTORS

Geared motors with the Pancake armature.



This high-torque, flat dc motor has six different geartrain options.

Until now, you have had good reason to think that a dc gearmotor couldn't give you the long life or reliability you wanted. You've also had good reason to think that designing an ac gearmotor into your product wouldn't give you the torque you needed.

It's time to think again.

We have added a geartrain to our standard motor, without taking anything away from its longevity, reliability, acceleration, or torque.

We've done all this, with very little increase in overall depth to give you a compact package that's low in price.

This gearmotor incorporates spur gears and is available with six geartrain ratios ranging from 15 to 1 all the way to 150 to 1.

Output speeds up to 200 rpm are available, and are dependent on gear ratio. And since the geartrain presents negligible inertia, acceleration is high at all speeds. Our gearmotor is, of course, reversible. And it's available with integral tachometers, too.

Our gearmotor is built with a Pancake.

This geared motor's low profile as well as its low mass and high torque result from its Pancake armature. There is no iron in this unique flat copper-disc armature. As a result, the motor operates smoothly at all speeds. And in addition, demagnetization is virtually zero.

An eight pole ferrite magnet field provides high coercive force, with greatly reduced motor weight. Brushes commutate directly on the armature conductors without arcing because armature inductance is negligible. An important advantage of this motor construction over conventional dc motors is long brush life (up to 10,000 hours of operation).

Where to use this gearmotor.

Our gearmotor is ideal wherever high torque, variable speed, or reversibility is required. For example: in automobiles, boats, or camping gear. In short, it is perfect for use in products designed for 12-volt battery operation. Now that you have two versions, with and without gears, all you have to decide is which to use where.

Specifications	U9FG	U12FG	U9FGT	U12FGT
Horsepower	1/40	1/15	1/80	1/24
Max. recommended motor speed	4000	4000	4000	4000
Operating voltages (VDC)	0-13	0-20	0-12	0-18
Rated current (Amps)	5 8	6 2	5 9	6 0
Stall current (Amps)	6 2	7 6	6 2	7 6
Motor resistance (Ohms)	85	75	85	75
Output speed (reversible) (RPM)*	0-150	0-190	0-130	0-175

*Dependent upon gear ratio

Tachometer constants	U9FGT	U12FGT
Output gradient (V/KRPM)	1 03	2 10
Ripple (% P-P)	5 0	5 0

Maximum Output—U9FG

Gear ratio	15 1	25 1	50 1	80 1	100 1	150 1
Torque (In.-lb.)	12 5	17 5	35 0	56 0	70 0	70 0
Speed (RPM)	150	90	45	28	22 5	15

Maximum Output—U12FG

Gear ratio	15 1	25 1	50 1	80 1	100 1	150 1
Torque (In.-lb.)	21 0	35 0	70 0	112	140	140
Speed (RPM)	169	121	60	36	30	21

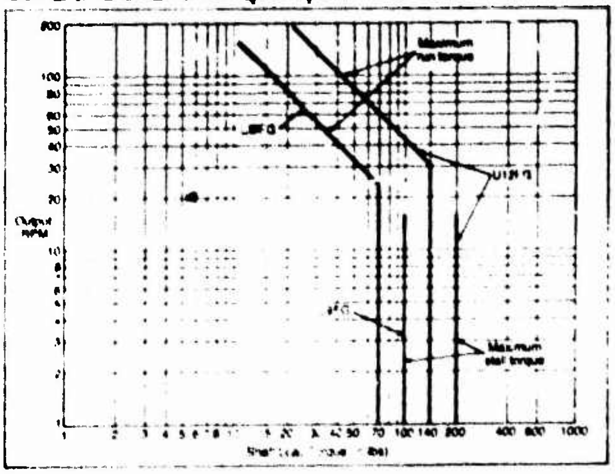
Maximum Output—U9FGT

Gear ratio	15 1	25 1	50 1	80 1	100 1	150 1
Torque (In.-lb.)	6 0	10 0	20 0	32 0	40 0	61 0
Speed (RPM)	130	78	38	24	20	13

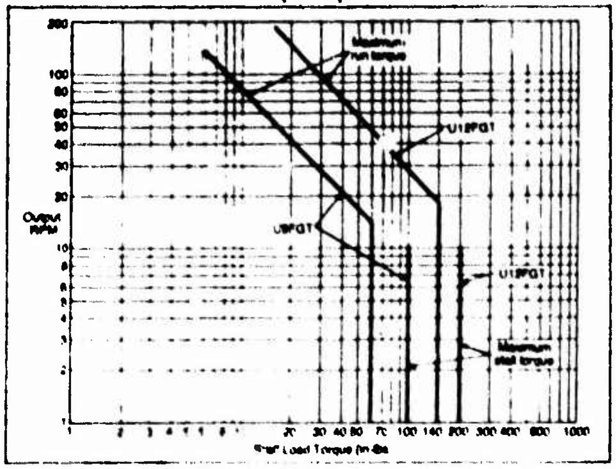
Maximum Output—U12FGT

Gear ratio	15 1	25 1	50 1	80 1	100 1	150 1
Torque (In.-lb.)	15 0	23 0	47 0	77 0	94 0	140
Speed (RPM)	175	115	56	34	28	18

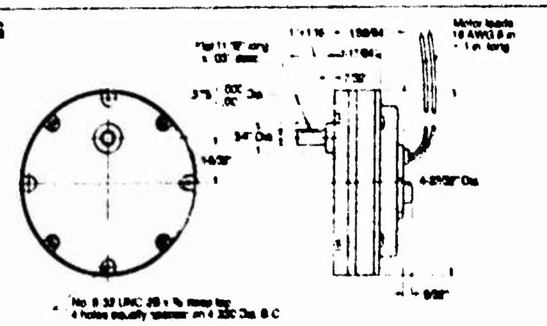
U9FG and U12FG Torque-speed characteristics.



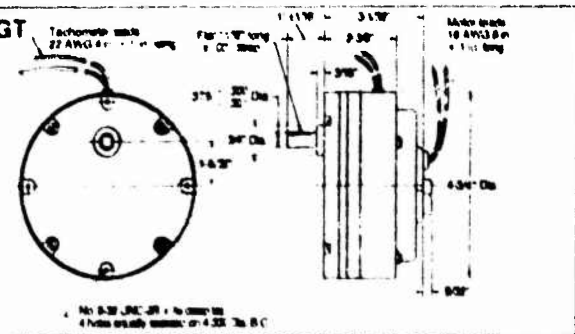
U9FGT and U12FGT Torque-speed characteristics.



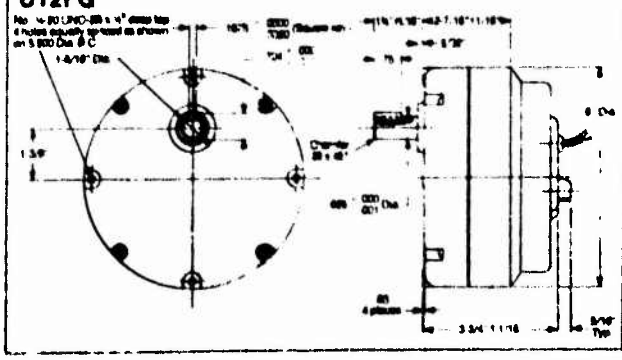
U9FG



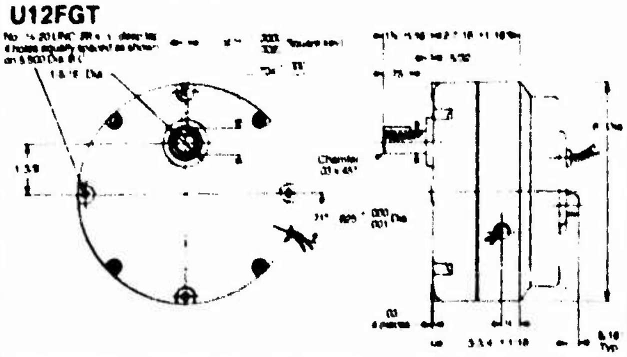
U9FGT



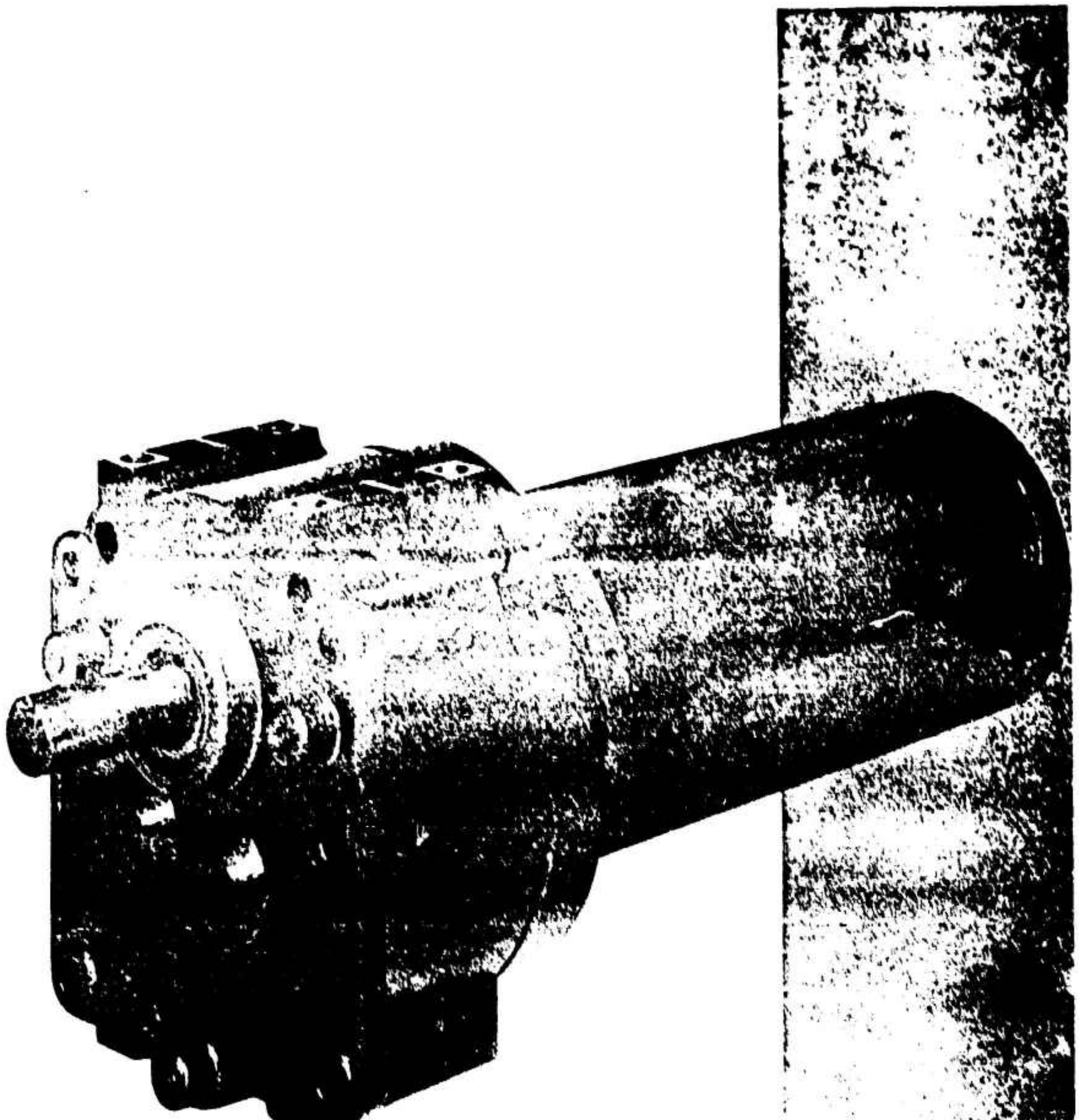
U12FG



U12FGT



RAE
CORPORATION



M400

Permanent Magnet Gearmotors

BULLETIN

RAE CORPORATION Permanent Magnet Gearmotors M4000 GIL 200 Series

The M4000 GIL 200 series permanent magnet gearmotor offers the design engineer a power rated and rugged product with field proven performance and reliability.

The specific performance characteristics presented in this catalog were selected as a cross section of the broad range of the performance potential of this product line. To help determine your exact needs select the unit that is closest to your requirements. We will ship the unit to you from the limited supply that is maintained by RAE. Included with the unit will be refinement procedures to assist you in obtaining data that will allow RAE engineers to modify the unit to your exact needs. The modifications can be made in both electrical performance and mechanical design.

Contact your RAE Representative and or RAE Corporation Motor Group, McHenry, Illinois 815—385-3500 for any assistance you may need.

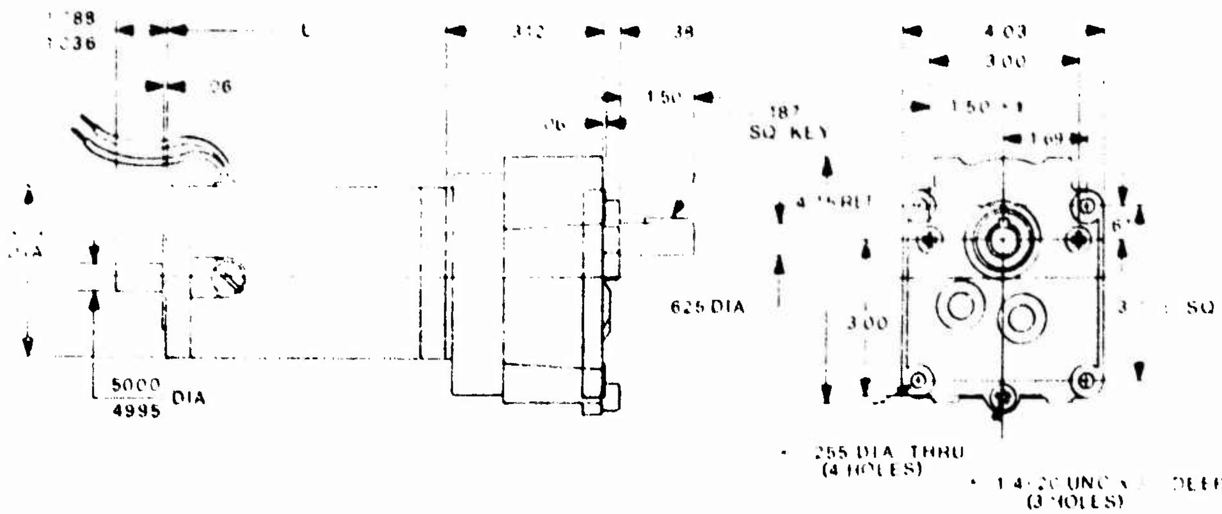
Special Features

GEAR REDUCER

- Needle bearings
- Ball thrust on shafts
- Oil filled
- Die cast housings
- Hardened steel gears
- Smooth quiet running
- Face or base mounting
- Ratios 11:1 to 254:1

MOTOR

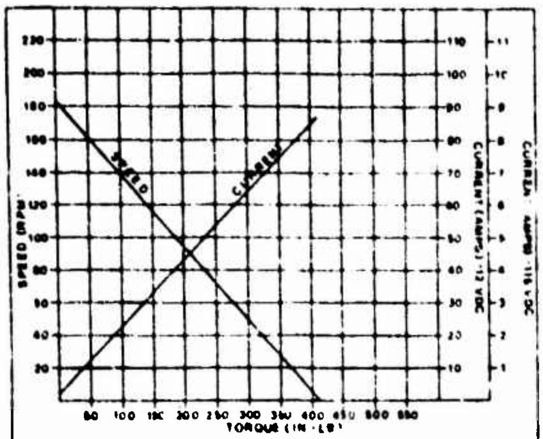
- Ball bearings
- Externally replacable brushes
- Totally enclosed
- Dynamically balanced armature
- Die cast end housings
- Ceramic permanent magnet field
- 12V to 230V



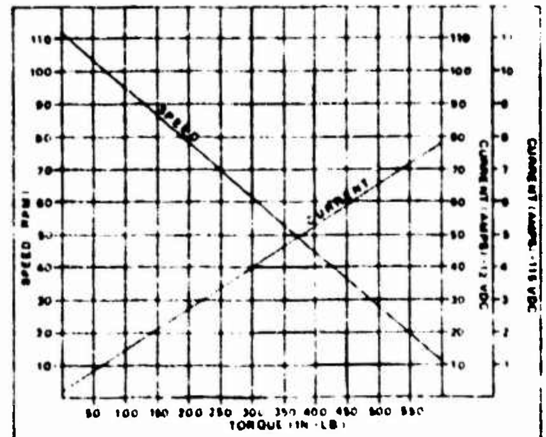
M4000 GIL 200 SERIES GEARMOTORS SPECIFICATIONS

STOCK PROTOTYPE	VOLTAGE	GEAR RATIO	LENGTH "L"	WT. LBS.	MAX. CONT. TORQUE RATING (in lbs.)	PERFORMANCE see curve no.
S 300	12	11:1	7	12	50	1
S 301	12	18:1	7	12	80	2
S 302	12	28:1	7	12	125	3
S 303	12	58:1	7	12	250	4
S 304	12	115:1	7	12	180	5
S 305	12	211:1	5	10	215	6
S 306	115	11:1	7	12	50	1
S 307	115	18:1	7	12	80	2
S 308	115	28:1	7	12	125	3
S 309	115	58:1	7	12	250	4
S 310	115	115:1	7	12	180	5
S 311	115	211:1	5	10	215	6

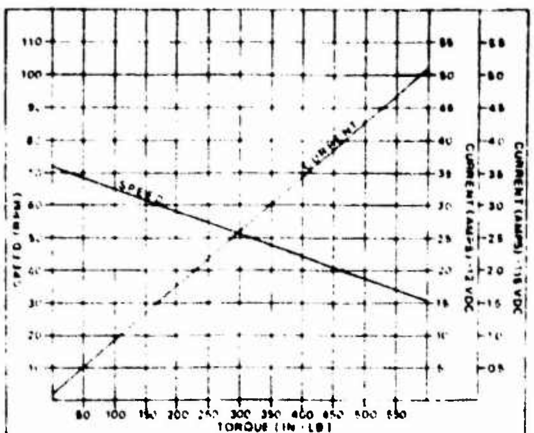
PERFORMANCE CHARACTERISTICS



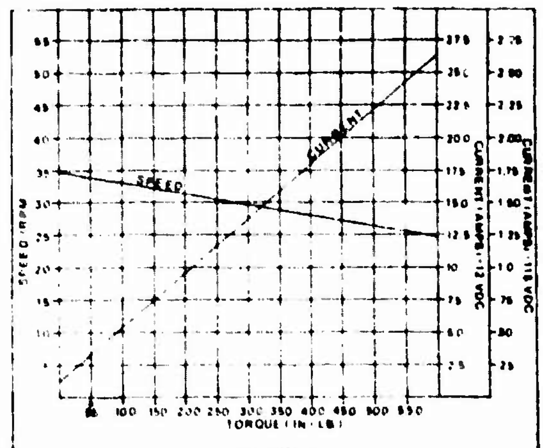
CURVE 1



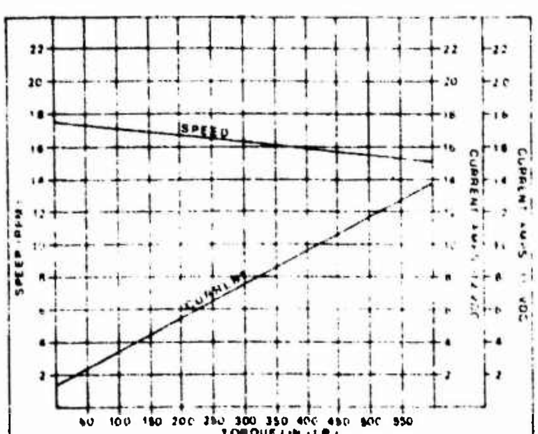
CURVE 2



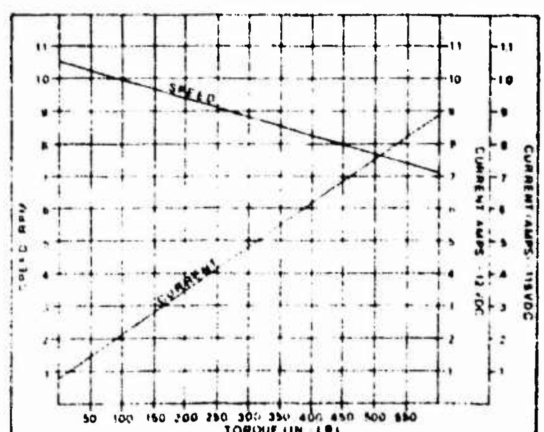
CURVE 3



CURVE 4



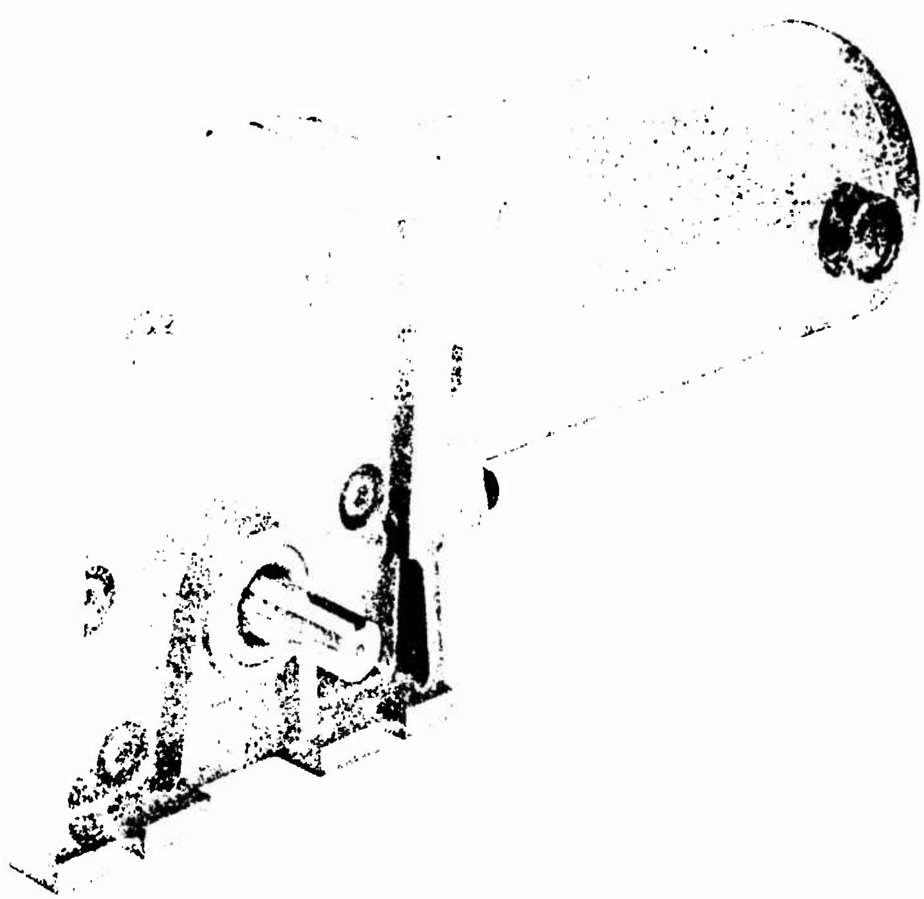
CURVE 5



CURVE 6

The prototype selected may not meet your needs or expectation. This is a normal finding in the prototype process However, the information you develop through the use of the prototype will help RAE engineers to recommend a special prototype. Modifications can be made both in electrical performance and mechanical design.

RAE®



Permanent Magnet Right Angle Gearmotors Model M4300 GRA133

BULLETIN 101

RAE Permanent Magnet Right Angle Gearmotors Model M4300 GRA133

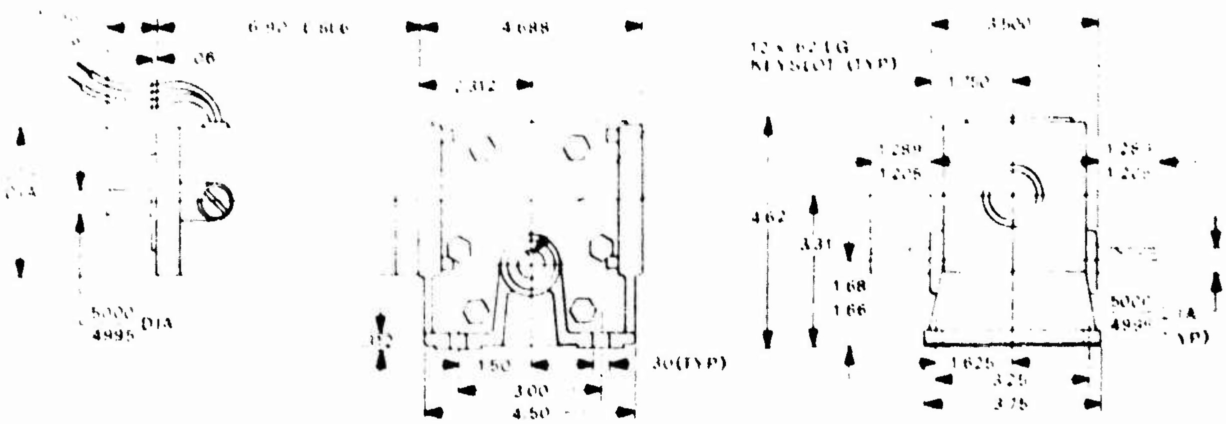
The M4300 GRA133 series permanent magnet gearmotor offers the design engineer a power rated and rugged product.

The specific performance characteristics presented in this catalog were selected as a cross section of the broad range of the performance potential of this product line. To help determine your exact needs select the unit that is closest to your requirements. We will ship the unit to you from the limited supply that is maintained by RAE. Included with the unit will be refinement procedures to assist you in obtaining data that will allow RAE engineers to modify the unit to your exact needs. The modifications can be made in both electrical performance and mechanical design.

Contact your RAE Representative and or RAE Corporation Motor Group, McHenry, Illinois 815—385-3500 for any assistance you may need.

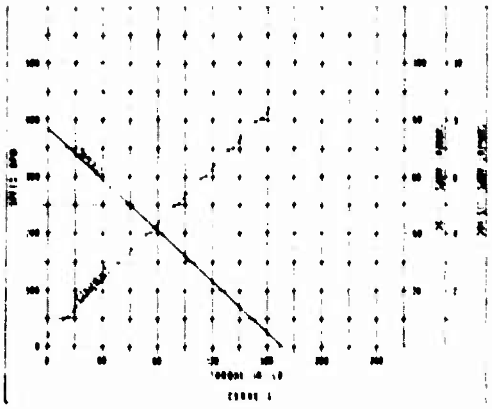
Advantages:

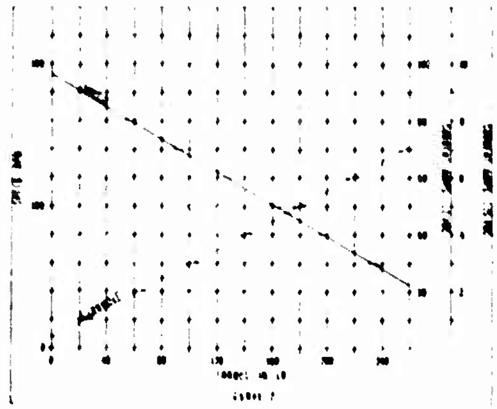
- HIGH CAPACITY — All anti-friction bearings
- LONG LIFE — Hardened steel worm bronze gear
- MAXIMUM EFFICIENCY — Oil lubricated gearhead
- MAXIMUM UTILITY — Totally enclosed motor
- REDUCED VIBRATION — Dynamically balanced armature
- EASIER SERVICE — Externally replaceable brushes

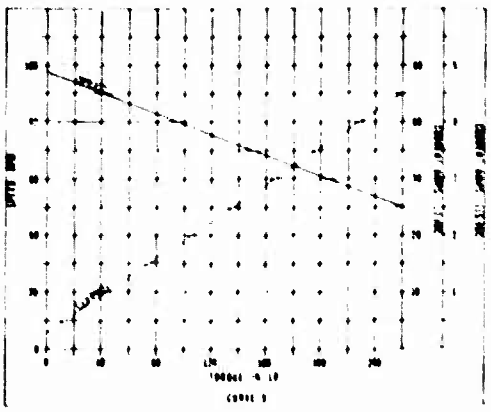


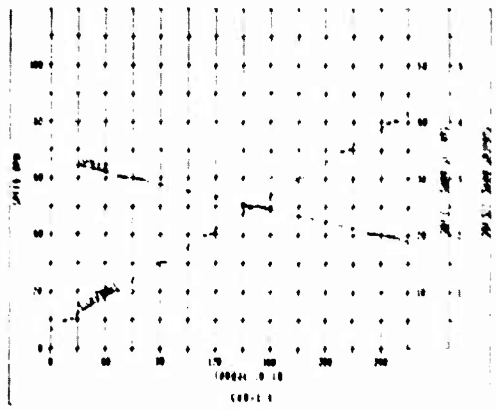
M4300 GRA133 GEARMOTORS SPECIFICATIONS

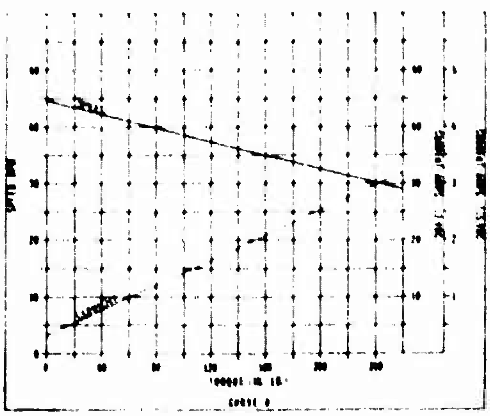
STOCK PROTOTYPE	VOLTAGE (1)	GEAR RATIO	WT. LBS.	MAX.CONT. TORQUE RATING (1) (in lbs.)	PERFORMANCE see curve no.
S-312	12	5 1/6:1	12.75	[illegible]	1
S-313	12	10 1/3:1	12.75	.9	2
S-314	12	20.5:1	12.75	59	3
S-315	12	30:1	12.75	72	4
S-316	12	45:1	12.75	88	5
S-317	12	60:1	12.75	99	6
S-318	115	5 1/6:1	12.75	19	1
S-319	115	10 1/3:1	12.75	29	2
S-320	115	20.5:1	12.75	59	3
S-321	115	30:1	12.75	72	4
S-322	115	45:1	12.75	88	5
S-323	115	60:1	12.75	99	6

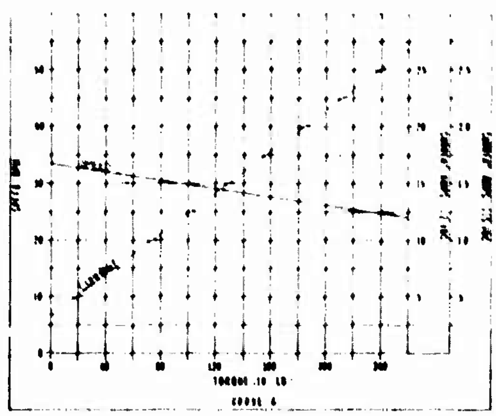








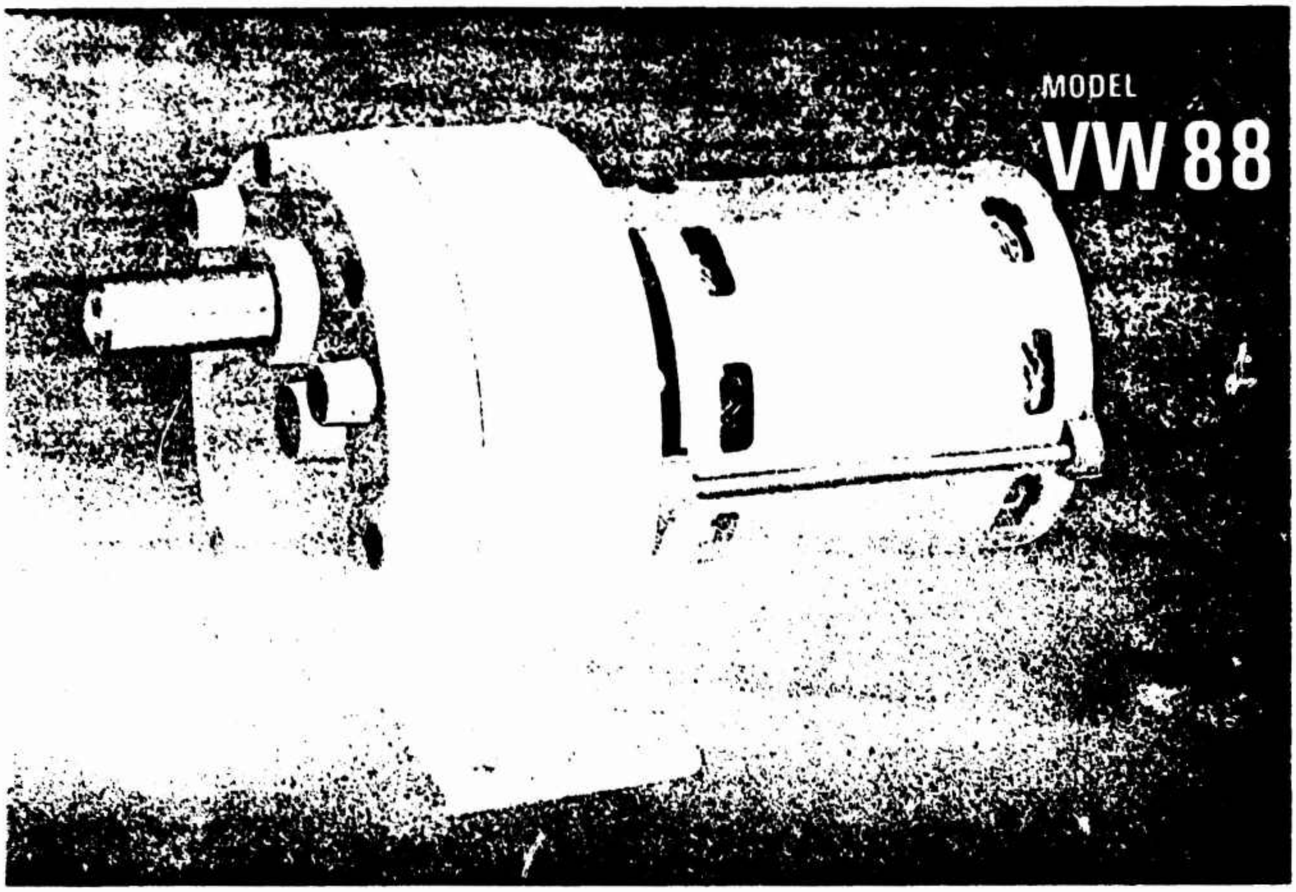




The prototype selected may not meet your needs or expectation. This is a normal finding in the prototype process. However, the information you develop through the use of the prototype will help RAE engineers to recommend a special prototype. Modifications can be made both in electrical performance and mechanical design.

A General Purpose GEARMOTOR

...To Fit Your Product



Designed to fill the gap between 1/4 HP and sub-fractional gearmotors

Features

- 4 types of motors
- Zinc die cast gear case
- Ball-bearing motor
- Oil-impregnated bronze bearings on all gear shafts
- Face or foot mounting
- Precision-cut gears for quiet running
- Parallel drive for maximum efficiency
- Weight: Approx. 8 lbs.

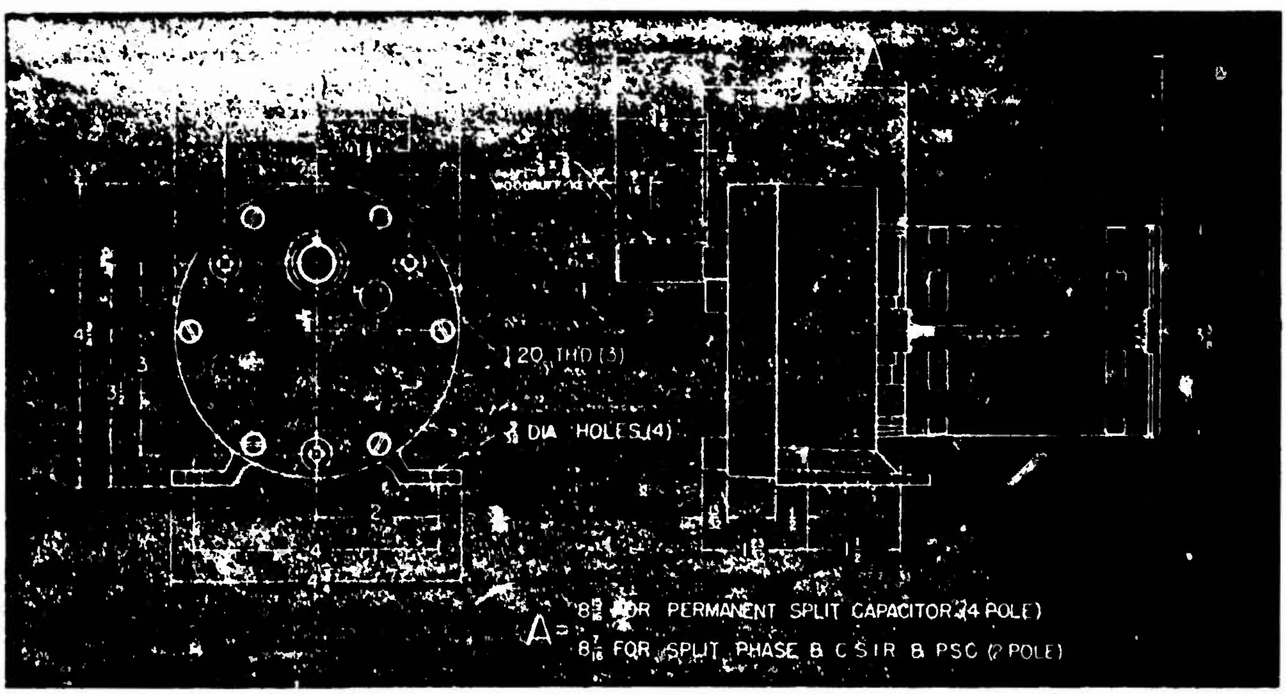
This versatile gearmotor is available with 4 types of electric motors, all of which may be totally enclosed.* All motors are electrically reversible, the P.S.C. motor is instantly reversible. Nine different standard ratios are available, producing a wide range of output speeds and torques as shown in the torque chart on the reverse side.

*Totally enclosed motors are rated intermittent duty only.

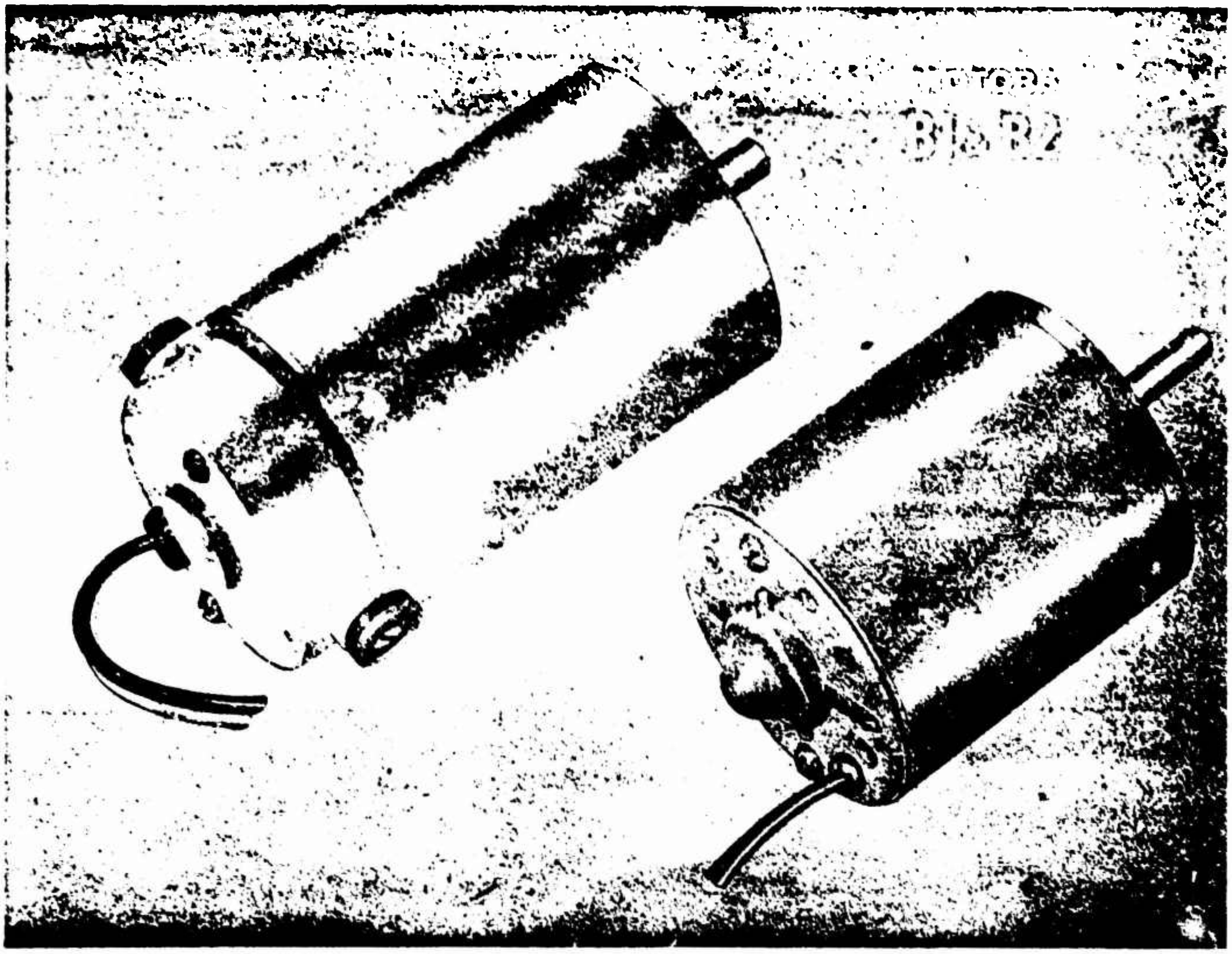
TORQUE CHART - Inch Lbs.

RATIO	PERM SPLIT CAP 1/12 H.P. 4-POLE: NO LOAD OUTPUT R.P.M.	F/L R.P.M. ● [illegible]	F/L TORQUE	PULL UP TORQUE	RECOMMENDED TORQUE	PERM. SPLIT CAP. 1/10 H.P. 2-POLE: NO LOAD OUTPUT R.P.M.	F/L R.P.M. ● [illegible]	F/L TORQUE	PULL UP TORQUE	RECOMMENDED TORQUE	SPLIT PHASE 1/10 H.P. 2-POLE: NO LOAD OUTPUT R.P.M.	F/L R.P.M. ● [illegible]	F/L TORQUE	PULL UP TORQUE	RECOMMENDED TORQUE	C. S. I. R. 1/10 H.P. 2-POLE: NO LOAD OUTPUT R.P.M.	F/L R.P.M. ● [illegible]	F/L TORQUE	PULL UP TORQUE	RECOMMENDED TORQUE
8.6:1	205	185	25.5	16	6	415	360	16	6	6	415	382	18	10	6	415	382	16	12	6
14.4:1	123	112	38	25	6	248	216	30	14	6	248	230	20	15	6	248	230	20	20	8
[illegible]	66.5	60	75	56	40	134	116	52	24	40	134	124	68	30	40	134	124	68	49	40
52:1	34	31	138	109	75	68	60	108	51	75	68	63	120	51	75	68	63	120	104	75
78:1	23	21	200	156	100	46	40	164	82	100	46	42.5	182	100	100	46	42.5	182	153	100
120:1	14	12.5	340	220	150	28	24	262	120	150	28	26	280	153	150	28	26	280	213	150
250:1	7	6.5	590	390	150	14	12	460	204	150	14	13.2	490	221	150	14	13.2	490	357	150
720:1	2.4	2.2	1750	1150	150	5	4.2	1360	800	150	5	4.5	1450	860	150	5	4.5	1450	1070	150
1447:1	1.2	1.1	3500	2300	150	2.5	2.1	2720	1200	150	2.5	2.3	2900	1320	150	2.5	2.3	2900	2140	150

The torques shown are intended as a guide to the user. We suggest that tests for the suitability of the gearmotor be made in the application. Recommended torques are for average conditions; under intermittent conditions the allowable torque may be increased. On applications where loads are near the maximum and/or long life is required, the recommended torque should be reduced.



Permanent Magnet MOTORS



This permanent magnet motor is designed for operations where speed control, low current draw, high starting torque, instant reversibility and/or dynamic braking action are required.

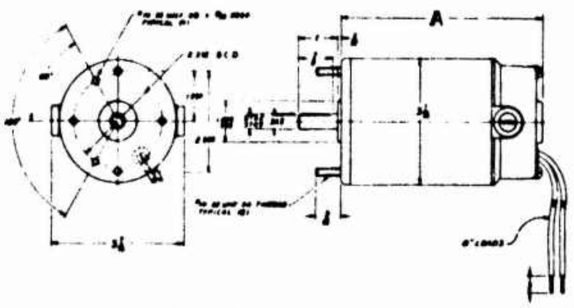
FEATURES:

- 1/20 H.P. to 1/4 H.P.
- 1650, 3300, 5000 rpm speeds
- Ball or Sleeve bearings
- External brushes for easy replacement
- Internal brushes for economy
- Die cast end bells
- Totally enclosed

B1 MOTOR

The B1 motor is designed principally for 115 Volt D.C. It features 18 slot lamination, a 16 bar commutator, ball or sleave bearings and external brushes.

STACK	A DIM
3/4	4.156
2	5.406

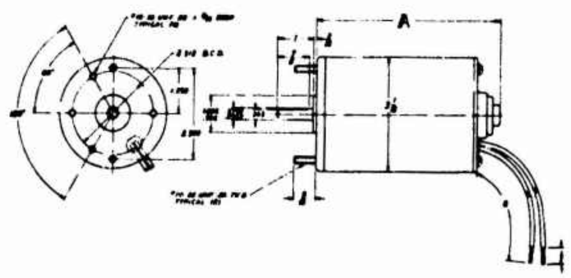


VW NUMBER	VOLT DC	H.P.	DUTY	STACK-INCHES	NO LOAD SPEED	NO LOAD AMPS	FULL LOAD SPEED	FULL LOAD AMPS	TORQUE IN. OZ.
AAB1	115	1/8	Cont.	2	6100	.18	5000	1.25	27
ABB1	115	1/4	Int.	2	6400	.3	5000	2.6	50
ACB1	115	1/20	Cont.	3/4	5800	.11	5000	.5	10
ADB1	115	1/12	Int.	3/4	6000	.15	5000	.8	17
AEB1	115	1/6	Cont.	2	3700	.25	3300	1.1	37
AFB1	115	1/4	Int.	2	4000	.35	3300	2.5	75
AGB1	115	1/20	Cont.	3/4	3600	.11	3300	.7	16
AHB1	115	1/12	Int.	3/4	3900	.2	3300	.62	24
AIB1	115	1/10	Cont.	2	2450	.15	1650	.95	57
AJB1	115	1/6	Int.	2	2600	.25	1650	1.25	75
AKB1	115	1/20	Cont.	3/4	2300	.11	1650	.5	30
ALB1	115	1/12	Int.	3/4	2500	.2	1650	.67	46

B2 MOTOR

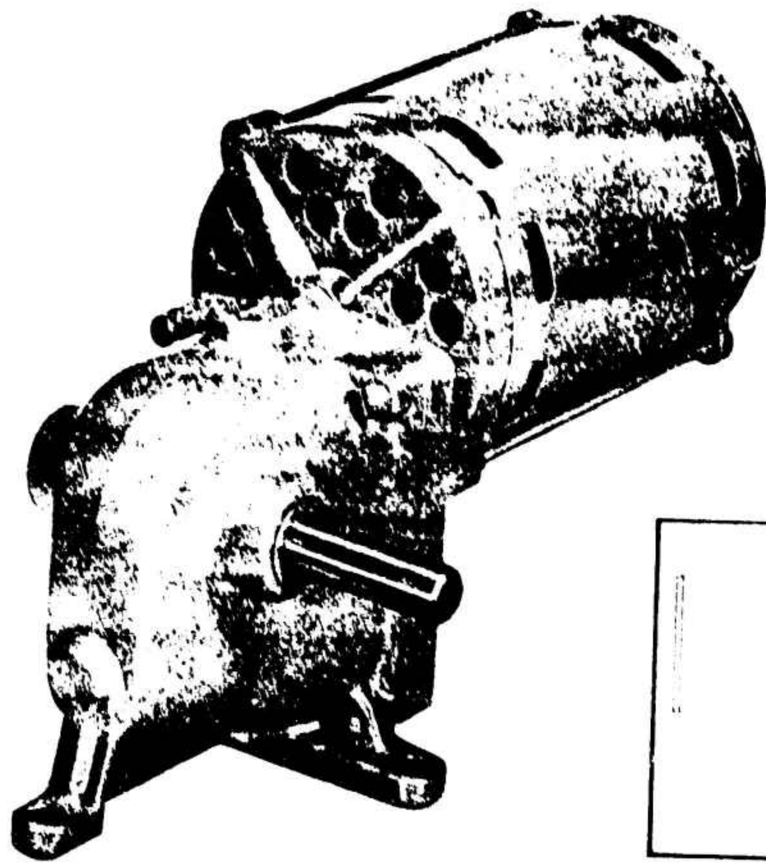
The B2 motor is designed principally for 12 Volt D.C. It features 10 slot lamination, a 10 bar commutator, ball or sleave bearings and internal or external brushes.

STACK	A DIM
3/4	4.193
2	5.403

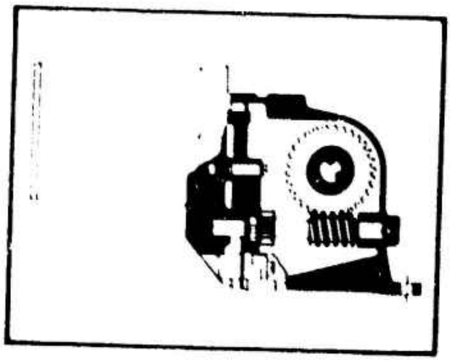


VW NUMBER	VOLT DC	H.P.	DUTY	STACK-INCHES	NO LOAD SPEED	NO LOAD AMPS	FULL LOAD SPEED	FULL LOAD AMPS	TORQUE IN. OZ.
AAB2	12	1/10	Cont.	2	6100	.9	5000	9.2	20
ABB2	12	1/6	Int.	2	6300	1.3	5000	16	33
ACB2	12	1/20	Cont.	3/4	5800	.4	5000	5.1	10
ADB2	12	1/12	Int.	3/4	6000	.55	5000	7.4	17
AEB2	12	1/10	Cont.	2	4000	.95	3300	10	33
AFB2	12	1/6	Int.	2	4200	1.4	3300	16.5	46
AGB2	12	1/20	Cont.	3/4	3800	.5	3300	5	15
AHB2	12	1/12	Int.	3/4	3950	.6	3300	7	30
AIB2	12	1/10	Cont.	2	2350	1	1650	9.6	57
AJB2	12	1/6	Int.	2	2450	1.35	1650	16.6	95
AKB2	12	1/20	Cont.	3/4	2400	.45	1650	4.7	30
ALB2	12	1/12	Int.	3/4	2500	.6	1650	7.3	47

A
High Torque, Light-Weight Gear Motor... *To Fit Your Product*



MODEL
VW33



This versatile gear box is now available with four different motors, to fit a wide variety of applications using spur gears in the high speed reductions for maximum efficiency, and worm and worm gear in final reduction to give right angle drive. If your application requires a "special," our engineering department will help you solve design problems or we will design a unit especially tailored to fit your needs.

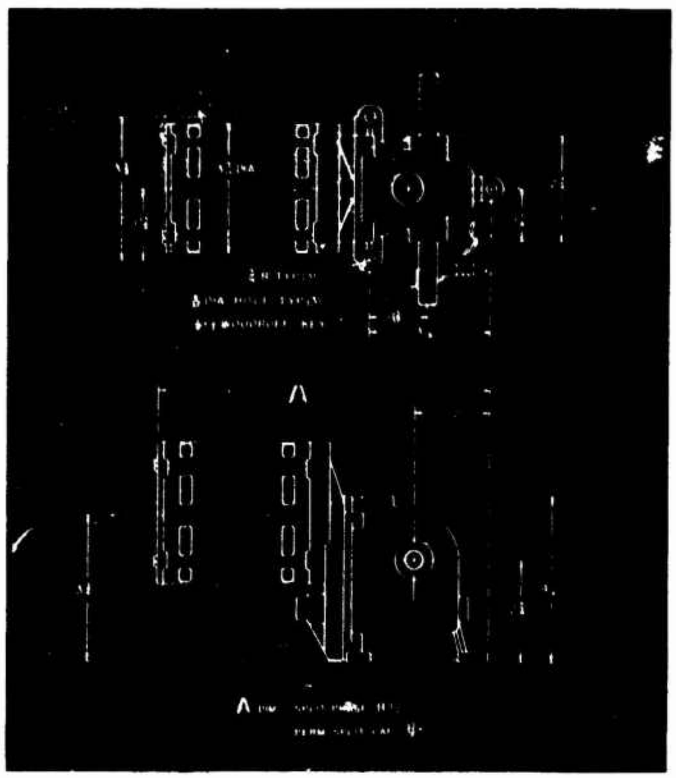
Engineering Data

Light-weight, compact design to save space in your product while maintaining maximum efficiency

TORQUE CHART – Inch Lbs.

RATIO	2 POLE PERM. SPLIT CAP.					4 POLE PERM. SPLIT CAP.					2 POLE SPLIT PHASE					2 POLE CAP. START IND. RUN				
	NO LOAD OUTPUT R.P.M.	FULL LOAD R.P.M. @ 3100 MOTOR SPEED	FULL LOAD TORQUE	STARTING TORQUE	RECOMMENDED TORQUE	NO LOAD OUTPUT R.P.M.	FULL LOAD R.P.M. @ 1600 MOTOR SPEED	FULL LOAD TORQUE	STARTING TORQUE	RECOMMENDED TORQUE	NO LOAD OUTPUT R.P.M.	FULL LOAD R.P.M. @ 3300 MOTOR SPEED	FULL LOAD TORQUE	STARTING TORQUE	RECOMMENDED TORQUE	NO LOAD OUTPUT R.P.M.	FULL LOAD R.P.M. @ 3300 MOTOR SPEED	FULL LOAD TORQUE	STARTING TORQUE	RECOMMENDED TORQUE
37:1	96	84	55	23	55	47	43	68	40	68	96	89	57	40	57	96	89	57	69	57
70:1	51	44	104	45	104	25	23	129	76	129	51	47	108	75	106	51	47	108	131	108
167:1	21	19	250	108	200	10	9	309	181	200	21	20	260	180	200	21	20	260	315	200
270:1	13	11	210	90	200	6.4	6	260	151	200	13	12	220	144	200	13	12	220	225	200
529:1	7	6	401	172	200	3.4	3	496	288	200	6.8	6.3	420	275	200	6.8	6.3	420	430	200
1288:1	3	2.5	958	410	200	1.4	1.3	1186	689	200	2.9	2.6	1004	658	200	2.9	2.6	1004	1026	200

The torques shown are intended as a guide to the user. We suggest that tests of the suitability of the gear motor be made in the application.
Recommended torques are for average conditions. However, under intermittent conditions the allowable torque may be increased. On applications where loads are near the maximum and or long life is required, the recommended torque should be reduced.



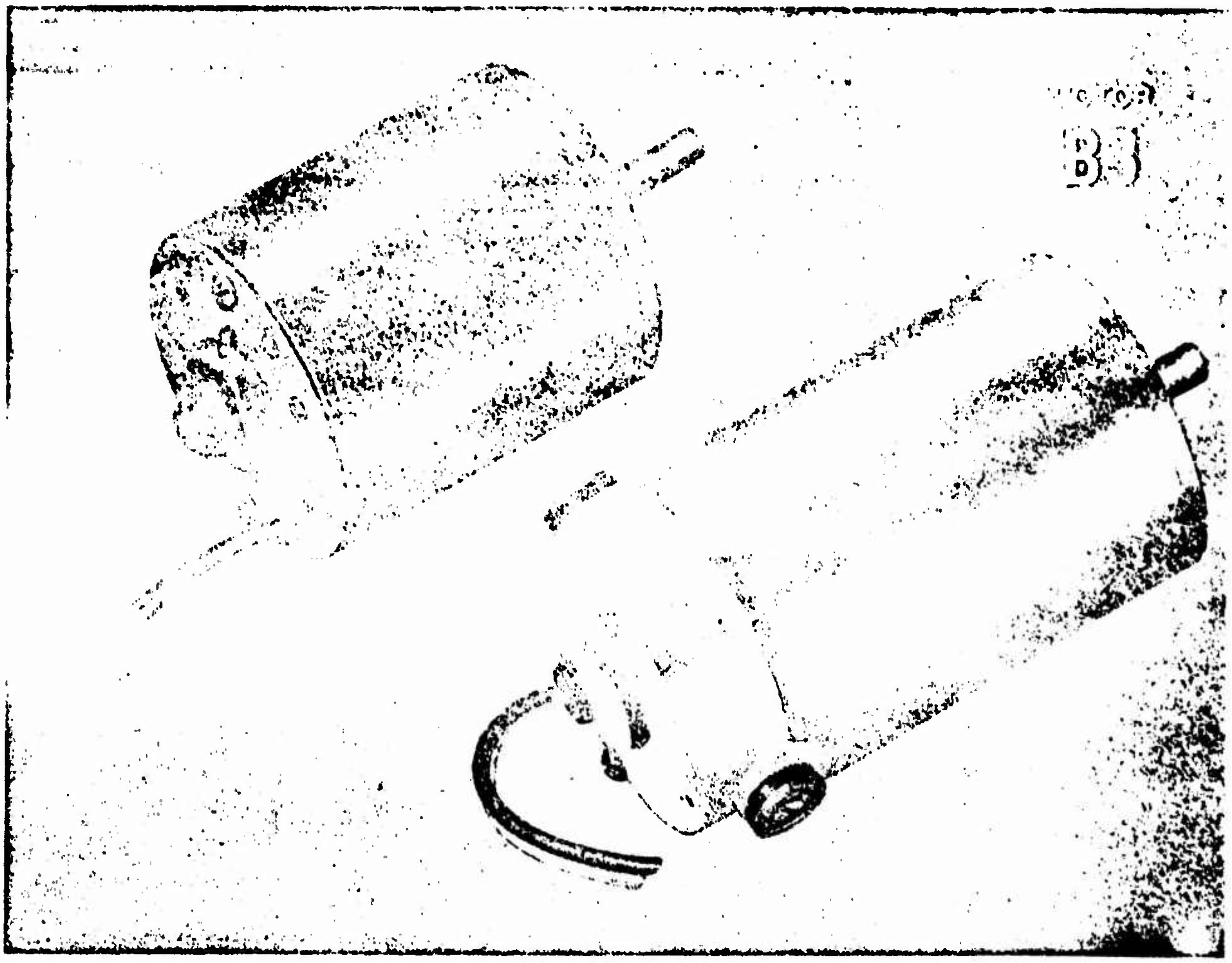
FEATURES

- Motor is integral part of gear unit
- Triple reduction precision cut gears
- Gears lubricated for life and totally enclosed in diecast housing
- Hardened output shaft with Woodruff key
- Foot mounting on gearcase

OPTIONS

- Thermal protection
- Face mounting
- Right hand output shaft extension (see drawing)
- Double output shaft

Permanent
Magnet
MOTORS



This permanent magnet motor is designed for operations where speed control, low current draw, high starting torque, instant reversibility and/or dynamic braking action are required.

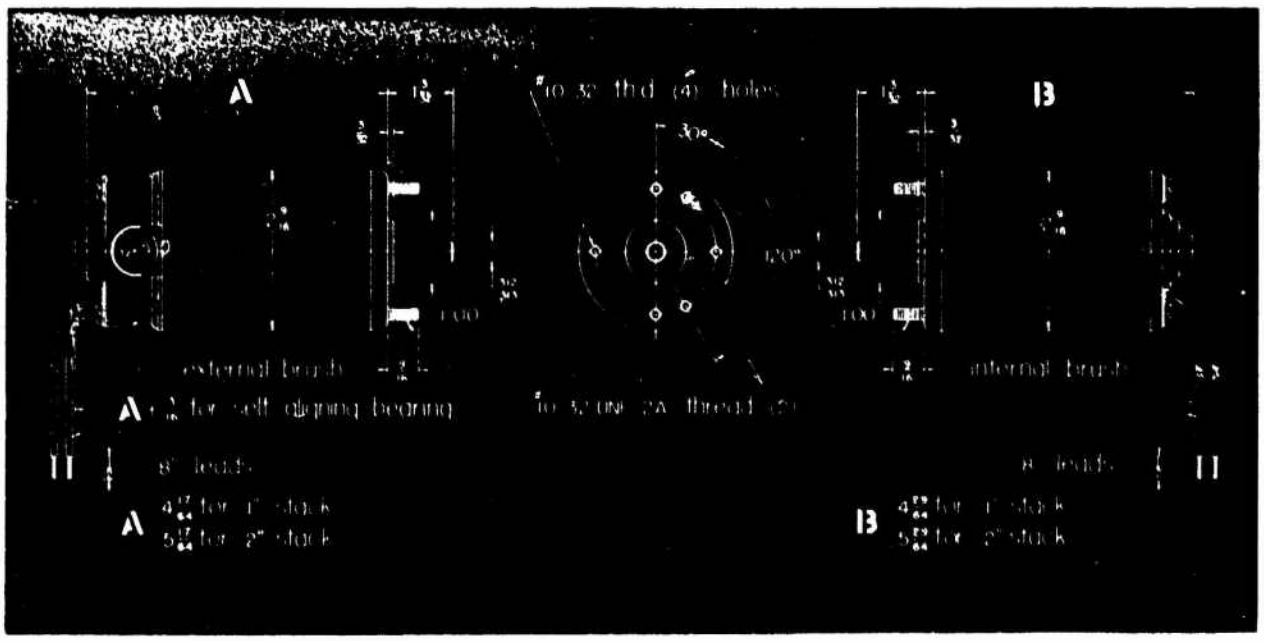
FEATURES:

- 1/30 H.P. to 1/15 H.P.
- 1650, 3300, 5000 rpm speeds
- Ball or Sleeve bearings
- External brushes for easy replacement
- Internal brushes for economy
- Die cast end bells
- Totally enclosed

VW NUMBER	VOLTAGE DC	H.P.	DUTY	STACK-INCHES	NO LOAD SPEED	NO LOAD AMPS	FULL LOAD SPEED	FULL LOAD AMPS	TORQUE IN. OZ.
AAB3	12	1/15	Cont.	2	6250	1.5	5000	6.1	13.5
ABB3	12	1/10	Int.	2	6400	1.6	5000	9.2	20
ACB3	12	1/30	Cont.	1	6100	1.1	5000	3.1	7
ADB3	12	1/20	Int.	1	6250	1.3	5000	4.5	10
AEB3	12	1/15	Cont.	1	4000	1.5	3300	6.1	19.5
AFB3	12	1/10	Int.	2	4100	1.8	3300	9.2	30
AGB3	12	1/30	Cont.	1	4100	1.1	3300	3.1	10
AHB3	12	1/20	Int.	1	4200	1.3	3300	4.5	15
AIB3	12	1/15	Cont.	2	2050	1.5	1650	6.1	39
AJB3	12	1/10	Int.	[illegible]	2100	1.6	1650	9.2	60
AKB3	12	1/30	Cont.	1	2000	1.1	1650	3.1	20
ALB3	12	1/20	Int.	1	2150	1.3	1650	4.5	30
AMB3	90	1/30	Cont.	1	6000	.15	5000	.42	7
ANB3	90	1/30	Cont.	1	3200	.15	2900	.42	11

The B3 motor is available for 12 Volt D.C. current or 90 Volt D.C. (115 Volt A.C. rectified). This motor features a 10 slot lamination and 10 bar commutator. It is available as internal or external brush design.

The torques shown are intended as a guide to the user. We suggest that tests of the suitability of the motor be made in the application. Recommended torques are for average conditions.



von weise

GEARMOTOR

. . .To Fit Your Product

The VW83 has been designed to meet your medium duty variable speed applications.
The standard spur and helical gears are injection molded from celcon for maximum efficiency and greatest economy. A combination of celcon and steel is available for higher load applications.
Motor bearings are available as ball bearings or permanently lubricated sintered bronze.

Heavy wall zinc die cast housings are used to give extra strength and smoother, quieter operation as well as greater support for bearings and shafts.
The output shaft is the same diameter through both its bearings for maximum strength on overhung loads and is double keyed to the output gear for greater torque.
The VW83 is available with an efficient Permanent Magnet motor and is standard in both 12 volt D.C. and 90 volt D.C. (115 volt A.C. rectified). For voltages and ratios other than those listed, contact the factory or our representative in your area.

TORQUE CHART–Inch Lbs.

CELCON GEARS				CELCON & STEEL GEARS			
Ratio	Full Load RPM	Full Load Torque	Rec. Torque	Ratio	Full Load RPM	Full Load Torque	Rec. Torque
17:1	170	7.2	7.2	14:1	207	8.7	8.7
28.1	103	12.4	12.4	24:1	120	14	14
55:1	52	24	15	48:1	60	27.5	27.5
110:1	26	48	15	96:1	30	55	50
157:1	18.5	74.7	15	149:1	19.5	78.8	50
263:1	11	117	15	250:1	11.6	123.4	50
522:1	5.6	231	15	495:1	5.86	244	50
1546.1	1.88	637	15	1471:1	1.97	668.8	50
3123:1	.93	1283	15	2965:1	.98	1352	50

Full Load: Motor speed 2900 RPM @ .42 amps
No Load: Motor speed 3250 RPM @ .1 amps

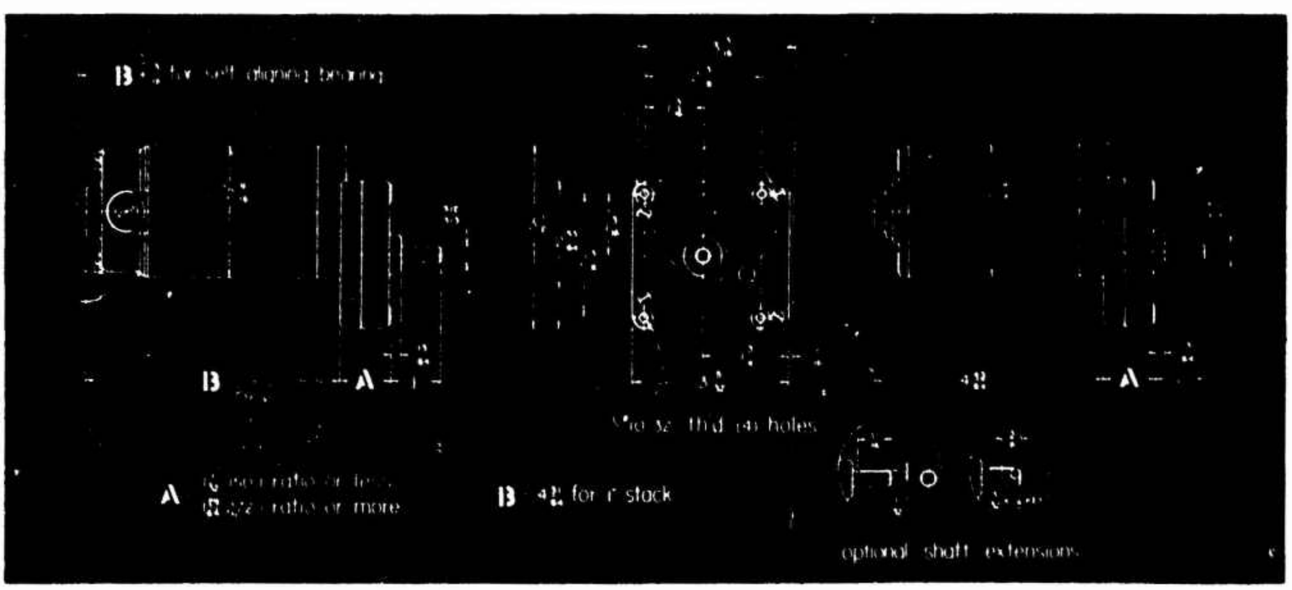
STEEL GEAR OPTIONS

2 Reductions — #2 gear Celcon-#4 gear steel
3 Reductions — #2 gear Celcon-#4 & #6 gear steel
4 Reductions — #2 & #4 gear Celcon-#6 & #8 gear steel
5 Reductions — #2, #4 & #6 gear Celcon-#8 & #10 gear steel

- Lubricated for life
- Face Mounted for rigidity
- Compact Design
- 18 standard gear ratios
- Special ratios & voltages to order

- Combination of celcon and steel gears
- Flat or keyway on output shaft
- Special ratios and voltages

The torques shown are intended as a guide to the user. We suggest that test for the suitability of the gear motor be made in the application.
Recommended torques are for average conditions. However, under intermittent conditions the allowable torque may be increased. On applications where loads are near the maximum and/or long life is required, the recommended torque should be reduced.



D.C. PERMANENT MAGNET PLANETARY GEARMOTORS

A-2430 BD & BL PLANETARY GEARMOTORS

general design specification.
MIL-M-8609

torque rating:
[illegible]" flange to 550 lb. in. continuous duty
3" flange to 1,100 lb. in. intermittent duty.

size:
1⅞" or 3" diameter. Length depends on reduction ratio

weight:
1⅞" flange 1.3 to 4.5 lbs. depending on ratio
3" flange 3.0 to 8.6 lbs depending on ratio.

gears:
Planetary gearing system. All gears are heat treated and ride on ball or roller bearings for greatest efficiency and long life.

shaft:
Carbon steel shaft per QQ-S-624 with 18 tooth spline serrations per ASA B5.15-1960 heat treated to Rc 45-48 (1⅞" flange) and Rc 29-33 (3" flange).

backlash:
Varies with reduction but average unit will have less than 3°.

bearings:
Ball bearings are double shielded, life lubricated for -55°C to +85°C operation. Special lubricants available for temperature extremes.

cover:
Motor - Type 1100 aluminum per QQ-A-411, chemical film per MIL-C-5541

geartrain:
Stressproof steel ETD 150 per QQ-S-624, cadmium plated per QQ-P-416.

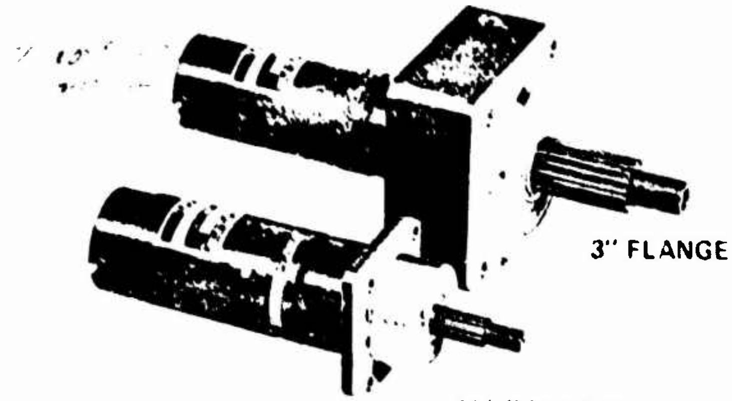
mounting flange:
C1045 corrosion resistant steel QQ-S-634 cadmium plated per QQ-P-416.

mounting:
Unit is mounted by means of pilot and four holes in flange.

marking:
Offset etching or roll-out stamping per MIL-STD-130.

life:
1000 hours continuous duty for 27 volt units per MIL-M-8609.

TYPE BD & BL



3" FLANGE

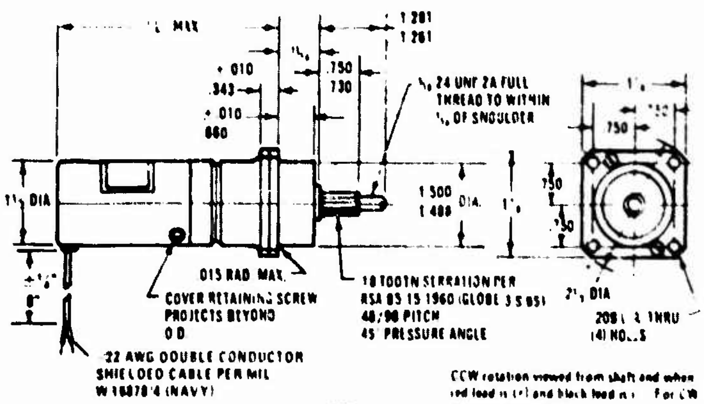
1⅞" FLANGE

TRW Globe's 1⅞" and 3" diameter planetary geartrains provide high torque outputs in a small package. Coupled to the Type BD or BL motor, they are ideal for business machinery, machine tools, aircraft, and missile applications.

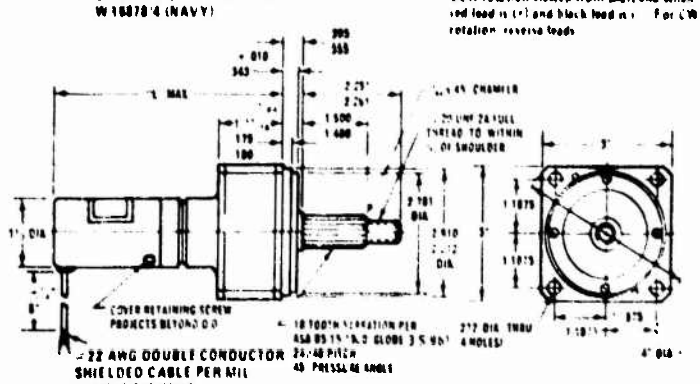
Anti-friction bearings in each planetary gear stage result in efficiencies of over 90% per stage.

OPTIONS AVAILABLE

- Electromechanical Brakes
- Speed Governors
- RFI Filters (integral or external) to meet MIL-I-6181 or MIL-I-26[illegible]
- Integral Tachometer Generators



CCW rotation viewed from shaft end when red lead is (+) and black lead is (-). For CW rotation reverse leads.



Note: Please consult TRW Globe Motors on the details of your mission requirements prior to preparing spec control prints.

STANDARD PART NUMBERS AND GEARMOTOR DATA

1 7/8 FLANGE

SPEED REDUCTION RATIO	TORQUE MULTIPLIER	MAX. CONT. RATING (lb. in.)	TYPE BD "L" max.	TYPE BD PART NO PREFIX *	TYPE BL "L" max.	TYPE BL PART NO PREFIX *
3.81:1	3.5	1.1	3.34	102A152	3.72	102A170
5.94:1	5.1	1.6		102A153		102A171
14.5 :1	13	4.1		102A156		102A174
21.1 :1	19	6.0	3.53	102A157	3.91	102A175
30.7 :1	27	8.6		102A158		102A176
55.3 :1	47	14.6		102A180		102A178
80.4 :1	68	21.0	4.09	102A181	4.47	102A179
117.0 :1	99	31.0		102A182		102A180
.85 178.8 :1	144	45.0		102A183		102A181
211.8 :1	171	53.0		102A189		102A199
308.0 :1	248	77.0		102A190		102A200
445.0 :1	360	100.0	4.28	102A191	4.66	102A201
647.0 :1	524	100.0		102A192		102A202
941.0 :1	762	100.0		102A193		102A203

3" FLANGE

SPEED REDUCTION RATIO	TORQUE MULTIPLIER	MAX CONT RATING (lb. in.)	TYPE BD "L" max.	TYPE BD PART NO PREFIX *	TYPE BL "L" max.	TYPE BL PART NO PREFIX *
308:1	248	77		102A929		102A939
445:1	360	112	5 3/8	102A930	5 3/4	102A940
647:1	524	164		102A931		102A941
941:1	762	238		102A932		102A942
1168:1	896	280		102A933		102A943
1696:1	1305	407		102A934		102A944
2466:1	1900	550	5 35/64	102A935	5 59/64	102A945
3584:1	2760	550		102A936		102A946
5211:1	4000	550		102A937		102A947

SHAFT DATA: 3" FLANGE

MIN EFF .0726 CIRCULAR TOOTH THICKNESS MAX EFF .0750
NUMBER OF TEETH 18
PITCH 24/48
PRESSURE ANGLE 45
LENGTH OF ENGAGEMENT 1 1/2 REF
MAX EFF .0750
.8818 MIN MEAS OVER TWO .080 PINS
MAX MEAS BETWEEN TWO .080 PINS .8322
Customer's Part for prototype use. Globe will broach holes in parts with .7195 I.D. broach hole starting .7205 diameter

SHAFT DATA: 1 7/8" FLANGE

MIN EFF .0357 CIRCULAR TOOTH THICKNESS MAX EFF .0369
NUMBER OF TEETH 18
PITCH 48/96
PRESSURE ANGLE 45°
LENGTH OF ENGAGEMENT 3/4 REF
.4397 MIN MEAS. OVER TWO .040 PINS
MAX. MEAS. BETWEEN TWO .040 PINS .3175
Customer's Part. For proto type use. Globe will broach holes in parts with .3575 I.D. broach hole starting .3585 diameter

Max. Cont. Torque: The values in this column are based upon geartrain strength and capability for 1000 hrs. minimum life. Max. rated torque of motor selected x torque multiplier ratio must not exceed these values.

Max. Intermittent Torque = 2 x Max. Cont. Torque.

Momentary Stall Torque = 5 x Max. Cont. Torque.

Minimum Efficiency = Torque Multiplier Ratio divided by Speed Reduction Ratio x 100.

BASIC MOTDR PERFORMANCE AND DATA

TYPE BD

VOLTAGE (v.d.c.)	SPEED (rpm)	TORQUE max. rated (oz. in.)	TORQUE nom. stall (oz. in.)	CURRENT max. no load (amps)	CURRENT max. rated load (amps)	CURRENT nom. stall (amps)	ARMATURE DASH NO ★
6	13,000-15,500	1.7	24	1.60	4.5	55.0	–2
6	10,000-12,000	2.3	19	1.30	4.6	35.0	–3
6	8,000- 9,500	3.2	15	.97	4.8	22.0	–4
12	12,500-14,500	1.8	24	.76	2.3	27.0	–5
12	10,000-12,000	2.4	19	.60	2.3	17.0	–6
12	8,000- 9,500	3.2	15	.49	2.3	11.0	–7
27	14,000-18,500	1.6	27	.39	1.0	15.0	–8
27	11,000-13,000	2.0	22	.30	1.0	9.8	–9
27	9,000-10,500	2.8	17	.24	1.0	6.4	–10
27	7,000- 8,500	3.6	14	.20	1.0	3.9	–11 —
50	10,500-12,500	2.1	20	.16	.5	4.6	–12
50	8,000- 9,500	2.8	16	.13	.5	2.9	–13
50	6,500- 8,000	3.7	13	.10	.5	1.8	–14
50	5,000- 6,500	3.5	10	.08	.4	1.2	–15
115	13,000-15,500	1.6	18	.09	.3	2.3	–16
115	11,000-13,000	2.2	14	.07	.3	1.5	–17
115	9,000-10,500	2.8	11	.06	.3	0.96	–18
115	7,000- 8,500	3.6	9	.05	.3	0.61	–19
115	6,000- 7,000	2.9	7	.04	.2	0.40	–20
115	4,500- 5,500	2.7	6.5	0.4	.2	0.26	–21

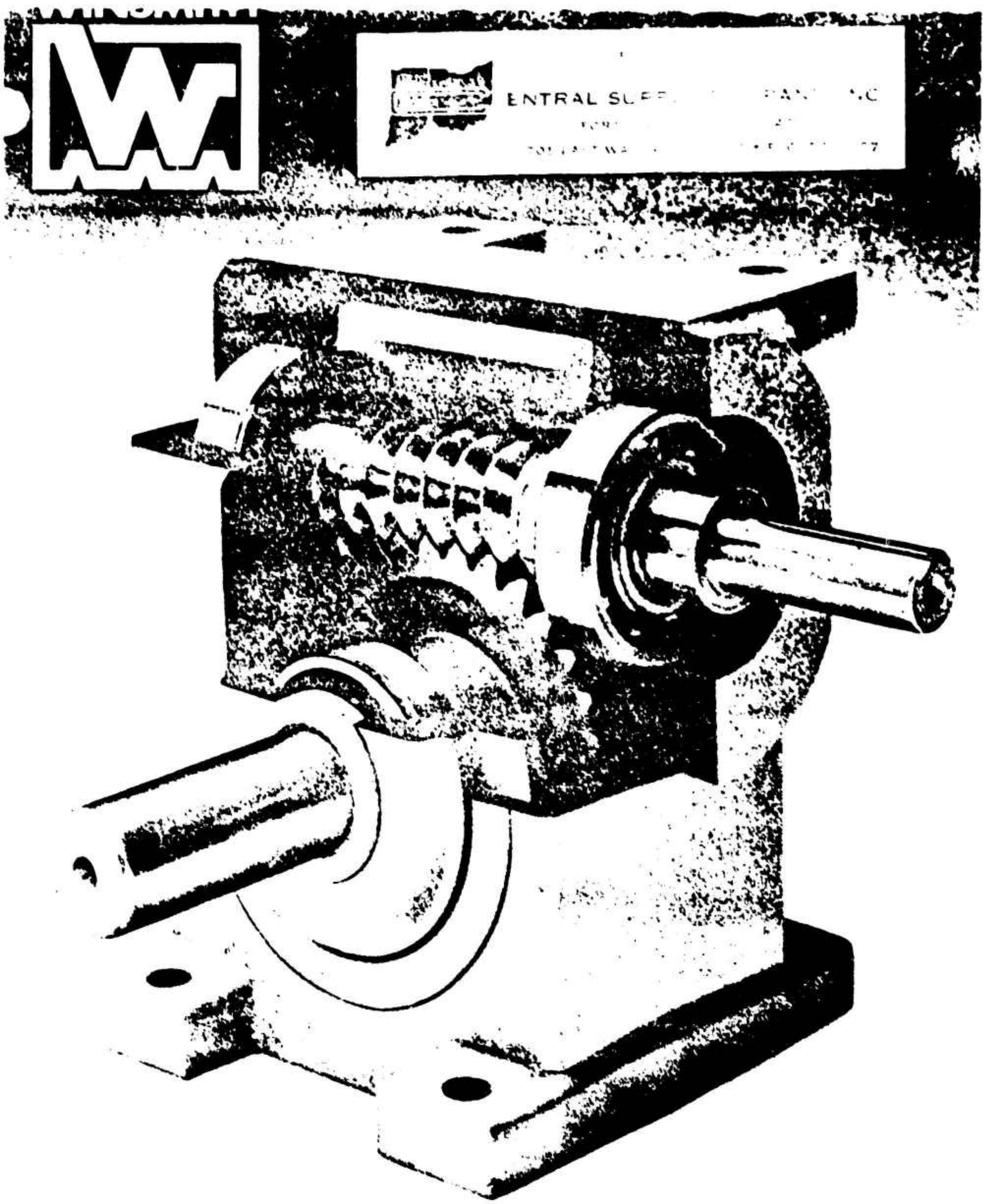
TYPE BL /30

VOLTAGE (v.d.c.)	SPEED no load (rpm)	TORQUE max. rated (oz. in.)	TORQUE nom. stall (oz. in.)	CURRENT max. no load (amps)	CURRENT max. rated load (amps)	CURRENT nom. stall (amps)	ARMATURE DASH NO. ★
6	10,000-12,500	3.3	37	1.50	5.2	62.0	–1
6	8,500-10,500	4.0	29	1.20	5.2	45.0	–2
6	6,500- 8,000	5.0	23	.93	5.1	28.0	–3
12	10,000-12,500	3.3	37	.71	2.6	36.0	–4
12	8,500-10,500	4.4	29	.56	2.7	22.0	–5
12	6,500- 8,000	5.0	23	.44	2.8	14.0	–6
27	11,500-14,000	2.9	42	.36	1.4	20.0	–7
27	8,500-10,500	3.7	33	.26	1.4	12.0	–8
27	7,000- 9,000	5.0	27	.22	1.4	8.0	–9
27	5,500- 7,000	6.0	21	.18	1.4	5.2	–10
50	8,500-10,500	3.8	31	.15	.72	5.9	–11
50	6,500- 8,000	5.0	25	.16	.74	3.7	–12
50	5,500- 7,000	6.5	20	.09	.73	2.4	–13
50	4,500- 5,500	7.5	16	.075	.66	1.5	–14
50	3,500- 4,500	6.0	12.5	.055	.43	0.94	–15
115	8,500-10,500	4.2	22	.065	.34	1.9	–16
115	7,000- 9,000	5.0	17	.055	.40	1.2	–17
115	5,500- 7,000	5.0	14	.045	.28	0.77	–18
115	4,500- 5,500	4.2	11	.035	.19	0.50	–19
115	4,000- 5,000	3.5	8.8	.030	.14	0.33	–20
115	3,000- 4,000	2.9	8.1	.025	.10	0.21	–21

NOTE: Part numbers in shaded areas not stocked by distributor. Available on request.

WHEN YOUR ORDER

***Part Number. Each of the basic motor armature windings (bottom chart) can be used with any of the gear ratios listed. To order state the gearmotor standard part number prefix plus a motor armature winding dash number. EXAMPLE: 102A152-8 is a 3.81:1 BD gearmotor with a -8 armature winding, 27 volts, 15,200 rpm, 1.6 oz. in. torque, etc. Consult TRW Globe Motors for variations in mechanical or electrical performance to suit specific applications.**



WINGEAR SPEED REDUCERS AND GEARMOTORS

D-47

RATINGS

ALL RATINGS [illegible] FOR AGMA CLASS I SERVICE

133

CENTER DISTANCE 1.333

RATIO	INPUT RPM	INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*INPUT OHL	*OUTPUT OHL
5	[illegible]	.93	.80	141	360.00	[illegible]	[illegible]
	[illegible]	.82	[illegible]	185	240.00	[illegible]	[illegible]
	[illegible]	.68	.58	203	180.00	[illegible]	[illegible]
	[illegible]	.51	.42	222	120.00	[illegible]	[illegible]
	[illegible]	.29	.23	243	60.00	[illegible]	[illegible]
	[illegible]	.12	.08	259	20.00	[illegible]	[illegible]
10	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	.54	.41	215	[illegible]	[illegible]	[illegible]
	[illegible]	.41	.31	240	80.00	[illegible]	[illegible]
	[illegible]	.33	.24	254	60.00	[illegible]	[illegible]
	[illegible]	.24	.17	268	40.00	[illegible]	[illegible]
	[illegible]	.14	.09	283	20.00	[illegible]	[illegible]
	[illegible]	.06	.03	294	6.67	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	269	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	283	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	293	[illegible]	[illegible]	[illegible]
30	[illegible]	.34	.21	222	60.00	[illegible]	[illegible]
	[illegible]	.26	.16	248	40.00	[illegible]	[illegible]
	[illegible]	.21	.13	261	30.00	[illegible]	[illegible]
	[illegible]	.16	.09	276	20.00	[illegible]	[illegible]
	[illegible]	.10	.05	292	10.00	[illegible]	[illegible]
	[illegible]	.04	.02	303	3.33	[illegible]	[illegible]
40	1800	[illegible]	[illegible]	[illegible]	45.00	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	291	[illegible]	[illegible]	[illegible]
50	[illegible]	.24	.12	208	36.00	95	259
	[illegible]	.18	.09	230	24.00	95	259
	[illegible]	.15	.07	242	18.00	95	259
	[illegible]	.11	.05	254	12.00	95	259
	[illegible]	.07	.03	258	6.00	95	259
	[illegible]	.03	.01	277	2.00	95	259
60	1800	.21	.09	[illegible]	30.00	[illegible]	[illegible]
	1200	.16	[illegible]	[illegible]	20.00	[illegible]	[illegible]
	900	.13	[illegible]	228	15.00	[illegible]	[illegible]
	600	.10	[illegible]	240	[illegible]	[illegible]	[illegible]
	400	.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100	.03	.01	255	1.67	95	[illegible]

175

CENTER DISTANCE 1.750

RATIO	INPUT RPM	INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*INPUT OHL	*OUTPUT OHL
5	[illegible]	1.80	1.59	[illegible]	[illegible]	[illegible]	557
	[illegible]	1.55	1.36	[illegible]	[illegible]	[illegible]	557
	[illegible]	1.33	1.15	404	[illegible]	151	557
	[illegible]	1.02	.87	457	120.00	151	557
	[illegible]	.60	.49	518	60.00	151	557
	[illegible]	.24	.18	563	20.00	151	557
10	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	120.00	[illegible]	557
	900	[illegible]	[illegible]	[illegible]	[illegible]	151	557
	600	[illegible]	[illegible]	[illegible]	[illegible]	151	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
15	[illegible]	.98	.80	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	.76	.61	478	80.00	[illegible]	[illegible]
	[illegible]	.62	.49	510	[illegible]	[illegible]	[illegible]
	[illegible]	.45	.35	[illegible]	40.00	[illegible]	[illegible]
	[illegible]	.26	.18	[illegible]	20.00	[illegible]	[illegible]
	[illegible]	.10	.06	594	6.67	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	.56	.42	[illegible]	[illegible]	[illegible]	557
	[illegible]	.46	.32	495	40.00	151	557
	[illegible]	.38	.25	[illegible]	30.00	[illegible]	557
	[illegible]	.28	.18	567	20.00	151	557
	[illegible]	.17	.10	598	10.00	144	557
	[illegible]	.07	.03	623	3.33	128	557
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	151	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	.39	.23	408	36.00	151	557
	[illegible]	.31	.17	456	24.00	143	557
	[illegible]	.25	.14	482	18.00	131	557
	[illegible]	.19	.10	510	12.00	117	557
	[illegible]	.12	.05	540	6.00	102	557
	[illegible]	.05	.02	560	2.00	89	557
60	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

200

CENTER DISTANCE 2.000

RATIO	INPUT RPM	INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*INPUT OHL	*OUTPUT OHL
5	[illegible]	2.06	1.84	[illegible]	[illegible]	218	481
	[illegible]	1.94	[illegible]	[illegible]	[illegible]	[illegible]	519
	[illegible]	1.53	1.62	[illegible]	[illegible]	[illegible]	557
	[illegible]	1.48	1.28	[illegible]	[illegible]	218	557
	[illegible]	.88	.74	[illegible]	[illegible]	218	557
	[illegible]	.35	.27	845	20.00	218	557
10	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	1.11	[illegible]	[illegible]	218	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	.15	.09	[illegible]	[illegible]	[illegible]	557
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	.38	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	.78	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	.65	.45	[illegible]	[illegible]	[illegible]	557
	[illegible]	.54	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	.43	.26	[illegible]	[illegible]	218	557
	[illegible]	[illegible]	.14	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	.05	[illegible]	[illegible]	[illegible]	557
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	.33	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	.53	.33	[illegible]	36.00	218	557
	[illegible]	.42	.25	[illegible]	[illegible]	[illegible]	557
	[illegible]	.35	.20	[illegible]	[illegible]	191	557
	[illegible]	.26	.14	[illegible]	[illegible]	[illegible]	557
	[illegible]	.16	.08	[illegible]	[illegible]	[illegible]	557
	[illegible]	.07	.03	[illegible]	[illegible]	134	557
60	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	557
	1200	[illegible]	.20	[illegible]	[illegible]	[illegible]	557
	900	[illegible]	.16	[illegible]	[illegible]	184	557
	600	[illegible]	.11	[illegible]	[illegible]	[illegible]	557
	400	.14	.06	[illegible]	[illegible]	154	557
	100	.06	.02	[illegible]	[illegible]	138	557

*Overhung load [illegible] at one shaft diameter from housing

237

CENTER DISTANCE 2.375"

RATIO	INPUT RPM	HP & TORQUE RATINGS INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*OHL INPUT OHL	OUTPUT OHL
5	1800	[illegible]	4.30	604	360.00	286	600
	1200	[illegible]	3.32	872	240.00	286	667
	900	[illegible]	2.85	[illegible]	180.00	266	723
	600	2.45	2.18	1148	120.00	266	828
	300	1.45	1.25	1310	60.00	266	1035
	100	[illegible]	[illegible]	[illegible]	20.00	[illegible]	1035
10	1800	2.80	2.50	876	180.00	266	783
	1200	2.25	1.98	1041	120.00	266	887
	900	1.86	1.62	1135	90.00	241	977
	600	1.38	1.18	1237	60.00	212	1035
	300	.78	.64	1348	30.00	179	1035
	100	.30	.23	1428	10.00	149	1035
15	1800	2.12	[illegible]	952	120.00	266	933
	1200	1.71	1.43	1127	80.00	266	1035
	900	1.41	1.17	1227	60.00	266	1035
	600	1.05	.85	1335	40.00	258	1035
	300	.61	.46	1453	20.00	[illegible]	1035
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1035
20	1800	1.68	1.39	970	90.00	266	1035
	1200	1.34	1.08	1133	60.00	242	1035
	900	1.11	.88	1225	45.00	219	1035
	600	.82	.63	1324	30.00	194	1035
	300	.47	.34	1431	15.00	165	1035
	100	.19	.12	1507	5.00	140	1035
30	1800	1.25	.94	989	60.00	[illegible]	1035
	1200	1.01	.74	1166	40.00	[illegible]	1035
	900	.85	.60	1266	30.00	266	1035
	600	.64	[illegible]	1374	20.00	264	1035
	300	.38	.24	1482	10.00	230	1035
	100	.16	[illegible]	1576	3.33	205	1035
40	1800	.98	.69	972	45.00	266	1035
	1200	.79	.54	1133	30.00	249	1035
	900	.66	.44	1222	22.50	227	1035
	600	.50	.31	1319	15.00	203	1035
	300	.30	.17	1424	7.50	176	1035
	100	.13	.06	1498	2.50	155	1035
50	1800	.80	.53	927	36.00	229	1035
	1200	.64	.41	1070	24.00	198	1035
	900	.53	.33	[illegible]	18.00	175	1035
	600	.40	[illegible]	[illegible]	12.00	[illegible]	1035
	300	.24	[illegible]	[illegible]	[illegible]	[illegible]	1035
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	1800	.67	.42	875	30.00	222	1035
	1200	.54	.32	1005	20.00	191	1035
	900	.45	.26	1078	15.00	173	1035
	600	.34	.18	1153	10.00	154	1035
	300	.21	.10	1238	5.00	135	1035
	100	.09	.03	1297	1.67	132	1035

263

CENTER DISTANCE 2.625"

RATIO	INPUT RPM	HP & TORQUE RATINGS INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*OHL INPUT OHL	OUTPUT OHL
5	1800	4.66	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	4.24	3.86	[illegible]	[illegible]	[illegible]	[illegible]
	900	3.94	3.57	1249	[illegible]	[illegible]	[illegible]
	600	3.31	2.96	1554	[illegible]	[illegible]	[illegible]
	300	2.00	1.73	1818	60.00	[illegible]	[illegible]
	100	.79	.64	2015	20.00	[illegible]	[illegible]
10	1800	3.87	3.31	1155	180.00	394	[illegible]
	1200	[illegible]	2.66	1398	120.00	333	828
	900	[illegible]	2.19	1533	90.00	299	910
	600	1.86	1.60	[illegible]	60.00	260	1035
	300	1.06	.88	[illegible]	30.00	217	1035
	100	.41	.31	1966	10.00	179	1035
15	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	1512	[illegible]	387	[illegible]
	900	1.88	1.58	[illegible]	[illegible]	[illegible]	[illegible]
	600	1.41	1.15	1817	40.00	[illegible]	[illegible]
	300	.81	.63	1991	20.00	[illegible]	[illegible]
	100	.32	.22	2115	6.67	237	[illegible]
20	1800	2.20	1.82	[illegible]	90.00	[illegible]	[illegible]
	1200	1.77	1.45	1525	60.00	307	1035
	900	1.47	1.19	1659	45.00	277	1035
	600	1.10	.86	1804	30.00	243	1035
	300	.63	.47	1962	15.00	205	1035
	100	.25	.17	2075	5.00	[illegible]	1035
30	1800	1.62	1.25	[illegible]	60.00	[illegible]	[illegible]
	1200	1.33	1.00	[illegible]	[illegible]	[illegible]	[illegible]
	900	1.12	.82	1716	30.00	[illegible]	[illegible]
	600	.85	.60	1876	20.00	[illegible]	[illegible]
	300	.50	.33	2052	10.00	[illegible]	[illegible]
	100	.21	.12	[illegible]	3.33	[illegible]	[illegible]
40	1800	1.27	.93	1295	45.00	371	1035
	1200	1.04	.73	1527	30.00	320	1035
	900	.87	.56	1658	22.50	291	1035
	600	.66	.43	1800	15.00	250	1035
	300	.40	.23	1956	7.50	224	1035
	100	[illegible]	.08	2086	2.50	195	1035
50	1800	1.03	.71	1238	36.00	[illegible]	[illegible]
	1200	.83	.55	1445	24.00	[illegible]	[illegible]
	900	.70	.45	1562	18.00	[illegible]	[illegible]
	600	.53	.32	1688	12.00	[illegible]	[illegible]
	300	.32	.17	[illegible]	6.00	[illegible]	[illegible]
	100	.14	.05	[illegible]	2.00	[illegible]	[illegible]
60	1800	[illegible]	.56	1167	30.00	277	1035
	1200	.89	.43	1354	20.00	236	[illegible]
	900	[illegible]	.35	[illegible]	15.00	213	[illegible]
	600	.44	.25	[illegible]	[illegible]	[illegible]	[illegible]
	300	.27	.13	[illegible]	[illegible]	[illegible]	[illegible]
	100	.12	.06	1726	[illegible]	[illegible]	[illegible]

300

CENTER DISTANCE 3.000"

RATIO	INPUT RPM	HP & TORQUE RATINGS INPUT HP	OUTPUT HP	OUTPUT TORQUE IN LB	OUTPUT RPM	*OHL INPUT OHL	OUTPUT OHL
5	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	867
	1200	[illegible]	5.26	[illegible]	[illegible]	[illegible]	963
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1029
	600	[illegible]	4.27	[illegible]	[illegible]	[illegible]	1160
	300	3.00	2.63	[illegible]	60.00	[illegible]	[illegible]
	100	[illegible]	.98	[illegible]	20.00	[illegible]	1332
10	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1332
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1332
	900	[illegible]	[illegible]	[illegible]	60.00	[illegible]	1332
	600	[illegible]	1.81	[illegible]	40.00	[illegible]	1332
	300	[illegible]	1.00	[illegible]	20.00	[illegible]	1332
	100	[illegible]	.36	[illegible]	6.67	345	1332
20	1800	[illegible]	2.75	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	1.35	[illegible]	[illegible]	[illegible]	[illegible]
	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	1800	[illegible]	1.86	[illegible]	60.00	[illegible]	1332
	1200	[illegible]	[illegible]	[illegible]	40.00	[illegible]	1332
	900	[illegible]	1.26	[illegible]	30.00	[illegible]	1332
	600	[illegible]	.93	[illegible]	20.00	[illegible]	1332
	300	[illegible]	.52	[illegible]	10.00	[illegible]	1332
	100	[illegible]	.18	[illegible]	3.33	[illegible]	1332
40	1800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	1800	[illegible]	1.06	[illegible]	36.00	[illegible]	1332
	1200	[illegible]	.85	[illegible]	24.00	[illegible]	1332
	900	[illegible]	.69	[illegible]	18.00	[illegible]	1332
	600	[illegible]	.51	2654	12.00	[illegible]	1332
	300	[illegible]	.26	2745	6.00	[illegible]	1332
	100	[illegible]	.09	2745	2.00	284	1332
60	1800	[illegible]	.84	[illegible]	30.00	[illegible]	[illegible]
	1200	[illegible]	.66	[illegible]	20.00	[illegible]	[illegible]
	900	[illegible]	.54	[illegible]	15.00	[illegible]	[illegible]
	600	[illegible]	.37	[illegible]	[illegible]	[illegible]	1332
	300	[illegible]	.18	[illegible]	[illegible]	[illegible]	[illegible]
	100	[illegible]	.05	[illegible]	[illegible]	[illegible]	[illegible]

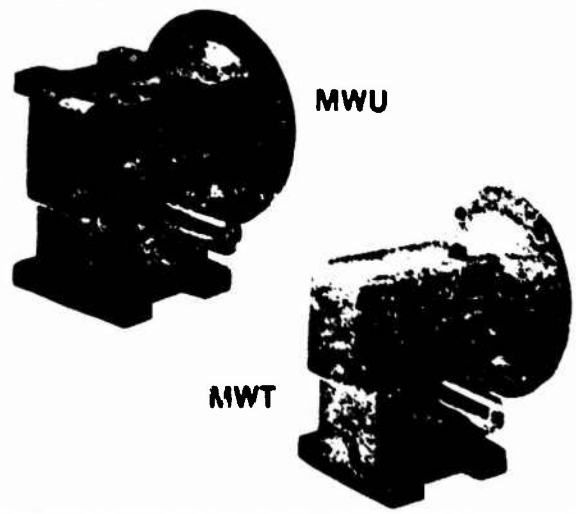
*Overhung load given at one shaft diameter from housing

2

motorized units—hollow input

SERIES: MWU
MWT

WORM GEAR TYPE–5 SIZES .03 H.P. to 6.30 H.P.
RATIO RANGE 5:1 to 60:1
MAX. OUTPUT TORQUE RANGE 197 to 3478 in. lbs.
UNIVERSAL MOUNTING (feet top & bottom) (U only)
FURNISHED WITH LUBRICANT
DOUBLE EXTENDED OUTPUT SHAFT IS STANDARD



MWU

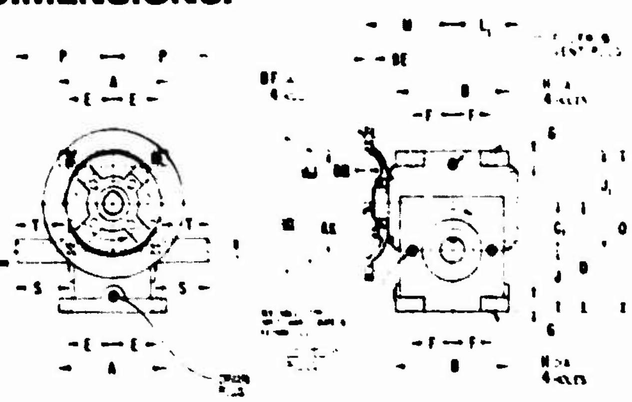
MWT

For Horsepower, Torque and Overhung
Load Ratings—See pages 2 and 3
For Service Factors—See page [illegible]

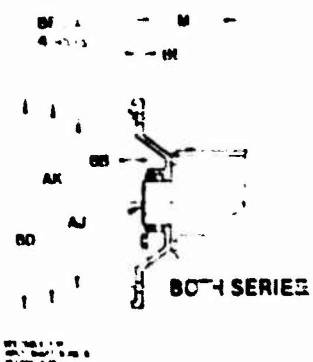
TABLE OF WEIGHTS Net. Wt

Size	[illegible]	175	[illegible]	237	[illegible]	300
MWU	[illegible]	2[illegible]	[illegible]	44	47	58
MWT	[illegible]	2[illegible]	[illegible]	42	[illegible]	56

DIMENSIONS:

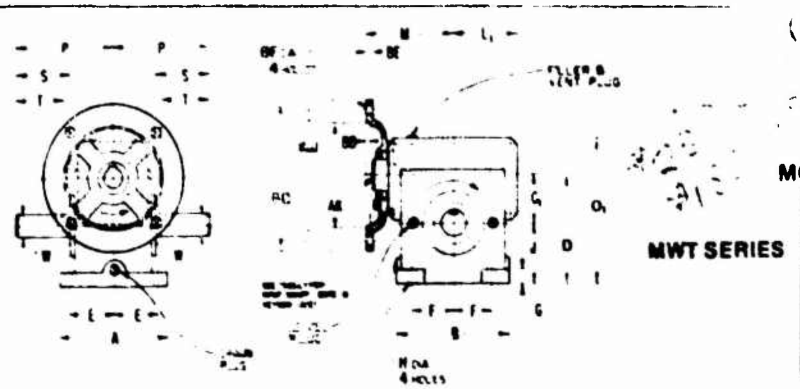


MWU SERIES



BOTH SERIES

Use above drawing for NEMA frame no's 213C, 215C, 182TC and 184TC.



MWT SERIES

MOTOR FRAME DIMENSIONS (in inches)

Frame No.	56C	143TC, 145TC, 182C, 184C	182TC, 184TC, 213C, 215C
[illegible]	[illegible]	[illegible]	[illegible]
AK	4 [illegible]	4 [illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
BD	6 [illegible]	6 [illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
BF Dia.	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
Bore*	[illegible]	[illegible]	[illegible]

• High Speed Shaft bore tolerance +.[illegible]" —.000".

SPEED REDUCER DIMENSIONS (in inches):

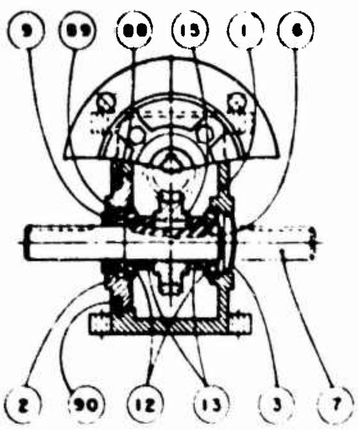
Size	A	B	C	D	E	F	G	H	J	J1	L1	M	O	O1	P	SLOW SPEED W*	SLOW SPEED S	SLOW SPEED T	SLOW SPEED Keyway	MAX. NEMA FRAME
175	4 7/8	4 11/16	[illegible]	4 1/8	[illegible]	1 1/4	3/8	13/32	2 1/8	3 3/4	2 13/16	4[illegible]	[illegible]	6[illegible]	4 3/8	1.000	2 9/16	2 1/4	1/4x1/8	56C
237	7	6 1/2	[illegible]	5[illegible]	[illegible]	2 1/4	3/8	9/16	3 1/2	5[illegible]	3 7/8	5[illegible]	8[illegible]	[illegible]	5[illegible]	1.250	3	2 3/4	1/4x1/8	184TC
300	7 3/4	7 1/8	[illegible]	7[illegible]	[illegible]	2 1/8	3/4	9/16	4	5 1/4	4	5 5/8	9 1/4	[illegible]	5 7/8	1.375	3 5/8	2 3/4	5/16x5/32	184TC

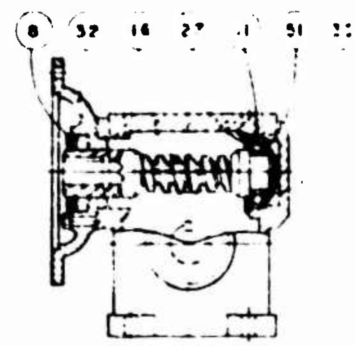
* Slow Speed Shaft diameter tolerance +.000" —.001".

For construction purposes, request certified dimension print.

motorized units

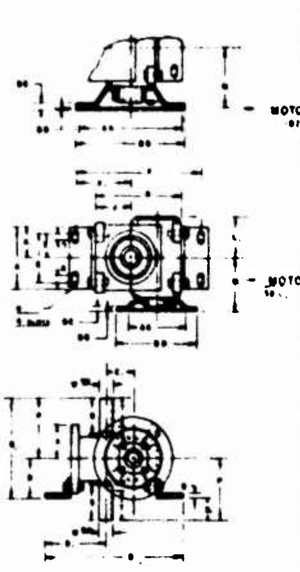
PARTS LIST:





Item No.	Description
1	Housing
2	Slow Speed Cover
3	Slow Speed Insert – Cover or Housing
6	Slow Speed Shaft – Single Extension
7	Slow Speed Shaft – Double Extension
8	Oil Seal – High Speed
9	Oil Seal – Slow Speed
11	Ball Bearing – High Speed
12	Roller Bearing – Slow Speed
13	Slow Speed Spacer – Not used on units 133 175 200
15	Slow Speed Worm Gear
16	High Speed Worm and Shaft
27	Bearing Retaining Ring – Internal
[illegible]	High Speed Shaft Retaining Ring – External
[illegible]	Motor Adapter
[illegible]	High Speed Spacer
54	Slow Speed Cover Retaining Ring – Internal
89	Slow Speed Adjustment Ring
90	Slow Speed Cover Filler Ring

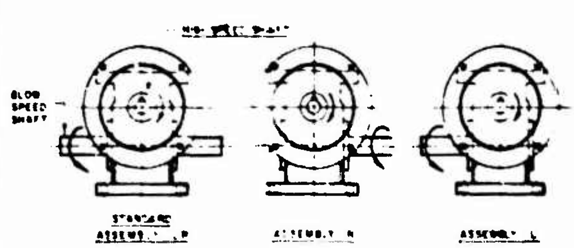
MOUNTING BRACKET DIMENSIONS (For MWU Series only)



SHALLOW MOUNT

DEEP MOUNT

SHAFT ARRANGEMENTS:



(A) When facing the input shaft Slow Speed Shaft is to left (L) or right (R) or both (LR)

(B) The input shaft may be driven in either direction

(C) Units may be mounted in floor, ceiling, sidewall or vertical position by relocating filler and vent plug

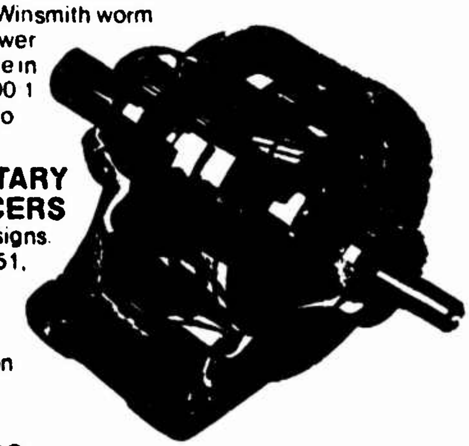
								SHALLOW MOUNT									DEEP MOUNT				
Size	A	A₁	E	E₁	H	R	X	B	B₁	D	F	F₁	O₁	S₁	B	B₁	D	F	F₁	O₁	S₁
[illegible]	4⅝	3⅜	3⅝	1⅞	⅝	½	2⅜	[illegible]	4½	2⅝	[illegible]	3⅝	[illegible]	1⅜	[illegible]	3⅜	3⅝	[illegible]	[illegible]	[illegible]	[illegible]
175	4⅜	2 5/16	3½	1¾	15/32	½	2 7/16	10⅜	4⅝	2¾	9⅛	4⅛	7⅛	1⅝	[illegible]	[illegible]	3½	[illegible]	3⅛	[illegible]	⅞
200	4⅝	2⅜	3½	1⅜	⅝	½	2⅝	10⅝	4⅝	2¾	9⅝	4⅝	[illegible]	1⅝	[illegible]	3⅝	3⅝	[illegible]	[illegible]	[illegible]	[illegible]
237	7¼	3⅝	5¾	2⅞	5/16	⅝	3½	13⅝	6	4⅛	12⅛	5¼	9⅝	[illegible]	[illegible]	5½	4⅝	[illegible]	4¾	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3½	13⅝	[illegible]	4⅝	12¾	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300	7¼	3⅝	5⅝	2⅞	5/16	⅝	3⅞	14¼	6½	4½	12¾	5¾	10⅜	1⅜	13¼	6	5	[illegible]	5¼	[illegible]	⅞

For additional dimensions, see chart on facing page.
For construction purposes, request certified dimension print.

WORM GEAR SPEED REDUCERS

Winsmith makes the widest range of speed reducers available as standard anywhere in the world. More than 13,000,000 standard variations of basic models of worm gear reducers which will suit your special needs are available. And every Winsmith reducer is the very best speed reducer modern materials and technology permit.

There are 49 basic designs of Winsmith worm gear reducers with input horsepower ranging from .04 to 56.78 available in standard ratios from 5:1 to 150,000:1 at maximum output torque up to 68,743 inch pounds.

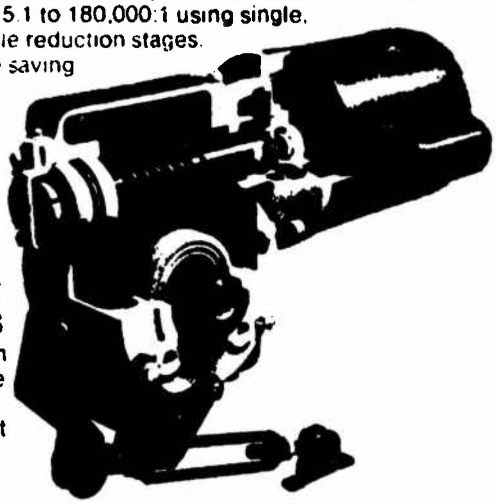


PLANETARY SPEED REDUCERS

Six basic planetary reducer designs. Input horsepower capacity ranges from .14 to 81.51, available in many standard ratios from 1.1:1 to 2300:1 (up to 50,000:1 available on request), and maximum output torque to 113,000 inch pounds. Winsmith design features assure maximum load carrying capacity, and smooth, quiet operation over a long operating life.

GEARMOTORS

H.P. range from .25 to 20, output R.P.M. from 350 to .009 and ratios from 5:1 to 180,000:1 using single, double and triple reduction stages. Winsmith's space saving modular design utilizes readily available NEMA C-face motors.

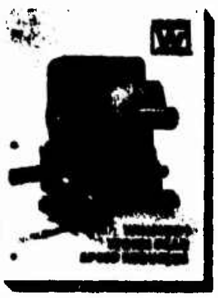


WORM GEAR SHAFT MOUNT SPEED REDUCERS

You get all the advantages of present Winsmith worm gear reducer designs ... plus a new bushing design enables just three sizes of reducers to accommodate shafts from 15/16" to 2-3/16" in 1/16" increments. And, an optional adapter and shaft assembly for use as a screw conveyor drive.

...smith Speed Reducers

WORM GEAR REDUCER CATALOG No. 100
256 pages packed with features, ratings, engineering data. 27 page reducer selection guide.



PLANETARY SPEED REDUCER CATALOG No. 110
24 page catalog with 5-step simple selection procedure. Includes service factors, complete specifications, rating charts.

GEARMOTOR CATALOG No. 130

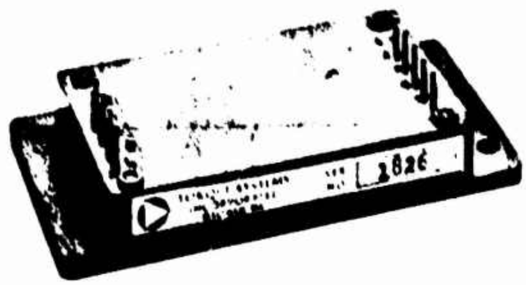
SHAFT MOUNT REDUCER CATALOG No. 140
24-page catalog tells you everything you need to know to put Winsmith's new worm gear shaft mount reducers to work in your drives.

Winsmith
Division of UMC Industries, Inc.
Springville, New York 14141
Telephone 716/592-9311

TORQUE SYSTEMS

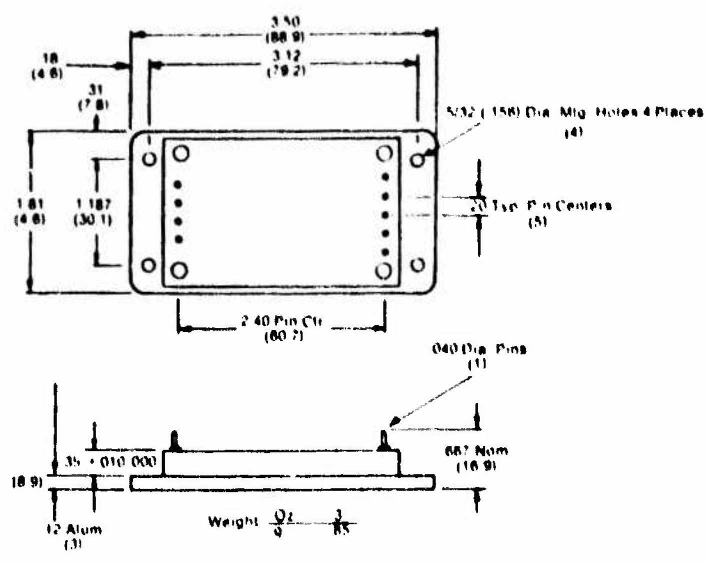
AN EG&G ROTRON COMPANY

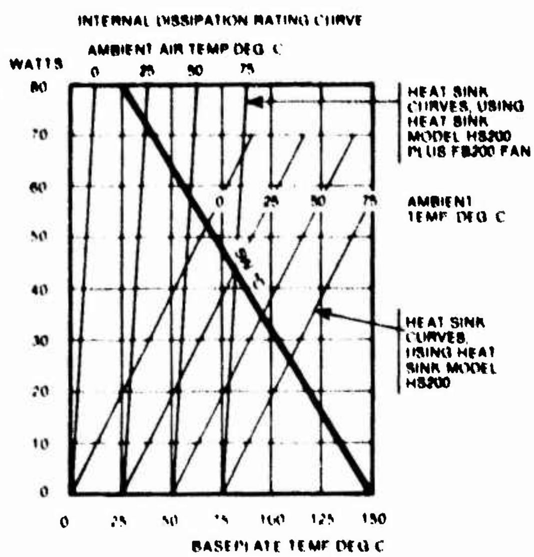
PA-111
60 WATT POWER OP-AMP
HEAT SINKABLE, BI-DIRECTIONAL
USING DUAL POLARITY SUPPLY



Torque Systems' power amplifiers are wide bandwidth, high performance, all silicon transistor, power amps specially designed to stand up to tough industrial requirements. The PA-111 is a linear, bi-directional class B short circuit protected amplifier. Its molded construction makes it highly resistant to mechanical shock and allows it to be mounted in any position.

This type of amplifier has its input, output, and voltage terminals designed to accept spring loaded sockets. Mating sockets which provide for the mounting of all input and feedback components as are necessary for the voltage amplification, current amplification, and servo operation and available as optional accessories. Data on mating sockets and performance specifications for the amplifier follow.





PA-111 PERFORMANCE SPECIFICATIONS

POWER SUPPLY REQUIREMENTS	
DC volts, nominal	± 15 VDC (± 10%)
DC volts, max.	± 22 VDC
Amps, full load	± 5 A
OUTPUT RATING	
Power, watts	60
Volts, max with ± 15V supply	± 12 VDC
Amps, internaly limited	± 5 A
FULL POWER RESPONSE	10 KHz
GAIN CHARACTERISTICS	
Open loop, pre-amp	60 KV/V
Crossover frequency, pre-amp	600 KHz
TEMPERATURE RANGE	
Base Plate	0 °C to 100 °C
Operating	0 °C to 50 °C
Storage	−30 °C to 70 °C

$90
1- $84
10- $63
100-

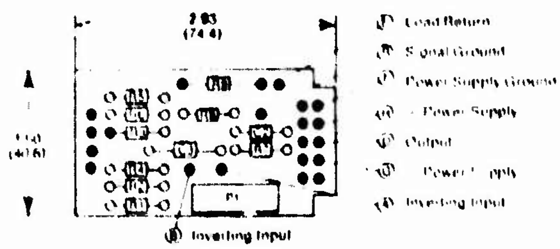
Printed in U.S.A.

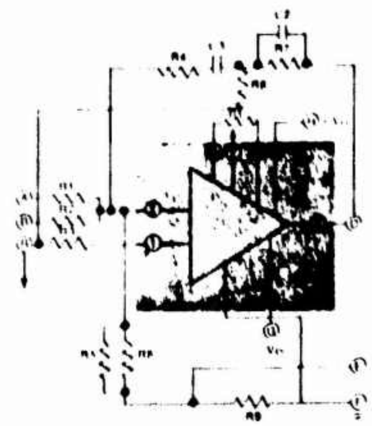
4/78

PA 111 INPUT CHARACTERISTICS

OP AMP USED	741C
INPUT IMPEDENCE	
Differential ohms	300 K
Common mode ohms	2 M
INPUT OFFSET VOLTS	
Nominal	5 mV, adj. to zero with 10 K external trimpot
Drift vs Temp	± 6 µV/°C
Drift vs Power supply	± 30 µV/V
INPUT CURRENT	
Bias	5 µA
Difference	± 2 µA
Difference vs Temp	2 nA/°C
INPUT VOLTAGE RANGE	
Absolute max differential	± 30 VDC
Common mode max	± 12 VDC
Common mode rejection	90 db

MATING SOCKET MODEL PC-110





MATING SOCKETS FOR USE WITH 111 SERIES AMPLIFIERS. The above figures show the physical layout and circuit diagram of the optional mating socket card for the 111 series amplifiers. Each card as supplied contains the necessary spring loaded sockets for mating with the amplifier terminal pins, the solder terminals for external cabling, the foil solder pads for component mountings, plus the balance potentiometer. The input and feedback components shown in the drawings and schematics are variable according to the application, and are typically customer selected and mounted. Not all of the components shown in the schematic are required for any given application, but the locations both physically and schematically for all components are shown to illustrate the versatility. For guidance on component selection for a particular application, consult with the factory. Technical notes are available for many applications, and will be supplied upon receipt of application information.

The terminal pin numbers for the basic amplifier are shown in the shaded circuit blocks, and the terminals for external cabling from the mating socket are shown lettered in the circuits outside of those blocks.

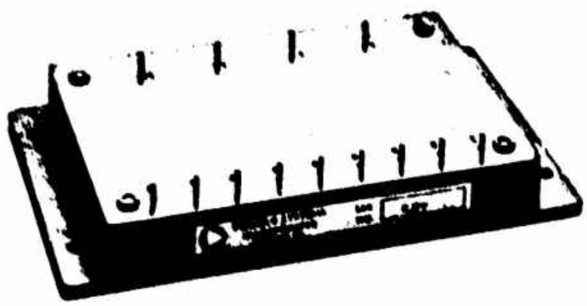
TORQUE SYSTEMS
INCORPORATED
AN EG&G ROTRON COMPANY

P.O. Box 588
225 Crescent Street
Waltham, Massachusetts 02254
Tel. (617)891 0230 Telex 92 3424

TORQUE SYSTEMS

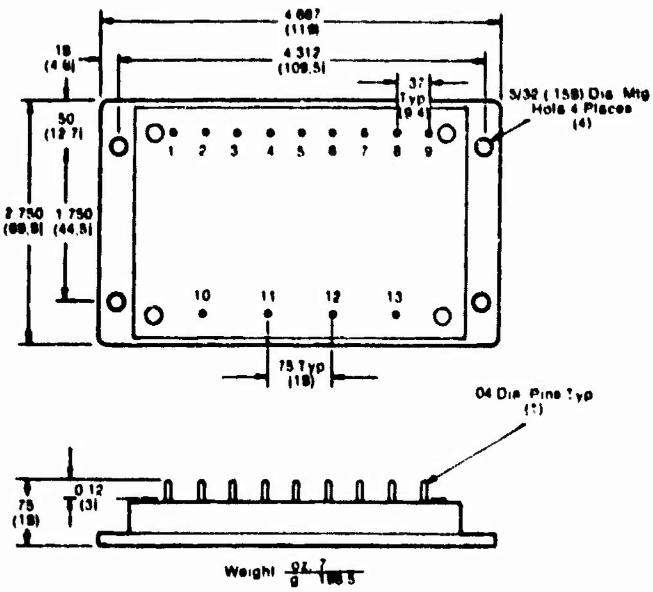
AN EG&G ROTRON COMPANY

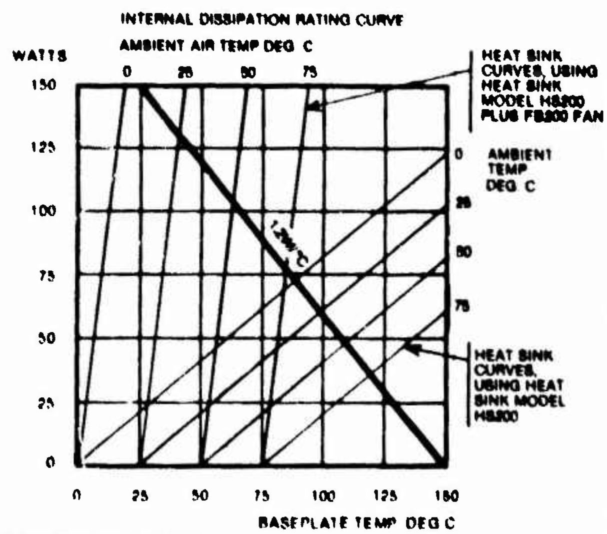
PA-223
110 WATT POWER OP-AMP
HEAT SINKABLE, BRIDGE OUTPUT
USING SINGLE POLARITY SUPPLY



Torque Systems' power amplifiers are wide bandwidth, high performance, all silicon transistor, power amps specially designed to stand up to tough industrial requirements. The PA-223 is a linear, bi-directional class B amplifier with full bridge output. Its molded construction makes it highly resistant to mechanical shock and allows it to be mounted in any position.

This type of amplifier has its input, output, and voltage terminals designed to accept spring loaded sockets. Mating sockets which provide for the mounting of all input and feedback components as are necessary for the voltage amplification, current amplification, and servo operation are available as optional accessories. Data on the mating sockets and performance specifications for the amplifier follow.





PA-223 PERFORMANCE SPECIFICATIONS

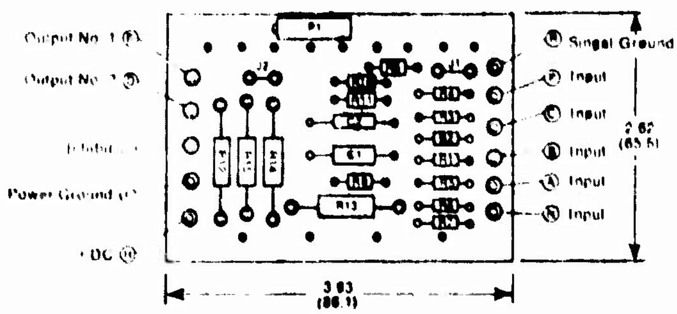
POWER SUPPLY REQUIREMENTS	
DC volts, nominal	+ 28 VDC (± 10%)
DC volts, max.	+ 32 VDC (50 VDC 10 sec)
Amps, full load	5 A
OUTPUT RATING	
Power, watts	110
Volts, max. with +28V supply	± 22 VDC
Amps, internally limited	± 5 A
FULL POWER RESPONSE	1000 Hz
GAIN CHARACTERISTICS	
Open loop, pre-amp	20 KV/V
Crossover frequency, pre-amp	600 KHz
Power stage D C gain	5 V/V
Power stage Crossover freq.	200 KHz
TEMPERATURE RANGE	
Base Plate	0°C to 100°C
Operating	0°C to 50°C
Storage	− 30°C to 70°C

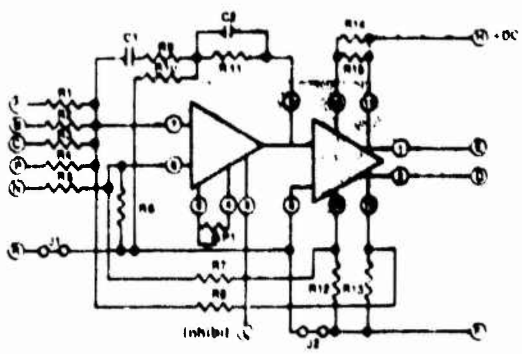
$200 each
10 $1.14
100 $1.07

PA-223 INPUT CHARACTERISTICS

OP-AMP USED	741C
INPUT IMPEDENCE	
Differential, ohms	300 K
Common mode, ohms	2 M
INPUT OFFSET VOLTS	
Nominal	± 5 mV, adj. to zero with 10 K external trimpot
Drift vs. Temp	± 6 µV/°C
Drift vs. Power supply	± 30 µV/%
INPUT CURRENT	
Bias	.5 µA
Difference	± .2 µA
Difference vs. Temp.	2 nA/°C
INPUT VOLTAGE RANGE	
Absolute max differential	± 30 VDC
Common mode max	± 12 VDC
Common mode rejection	90 db

MATING SOCKET MODEL PC-220





MATING SOCKETS FOR USE WITH PA-223 AMPLIFIER: The above figures show the physical layout and circuit diagram of the optional mating socket card for the PA-223 amplifier. Each card as supplied contains the necessary spring loaded sockets for mating with the amplifier terminal pins; the solder terminals for external cabling. The input and feedback components shown in the drawings and schematics are variable according to the application, and are typically customer selected and mounted. Not all of the components shown in the schematic are required for any given application, but the locations both physically and schematically for all components are shown to illustrate the versatility. For guidance on component selection for a particular application, consult with the factory. Technical notes are available for many applications, and will be supplied upon receipt of application information.

The terminal pin numbers for the basic amplifier are shown in the shaded circuit blocks, and the terminals for external cabling from the mating socket are shown lettered in the circuits outside of those blocks.

PA 223 Application Note

The PA-223 features an "inhibit" capability. The amplifier may be inhibited by the application of a low level signal to mating socket pin "L" (Amplifier pin "3")

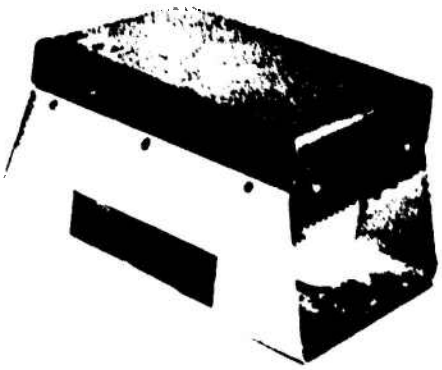
Specifications subject to change without notice

TORQUE SYSTEMS INCORPORATED
AN EG&G ROTRON COMPANY
P.O. Box 588
225 Crescent Street
Waltham, Massachusetts 02254
Tel. (617)891-0230 Telex 92-3424

TORQUE SYSTEMS

AN EG&G ROTRON COMPANY

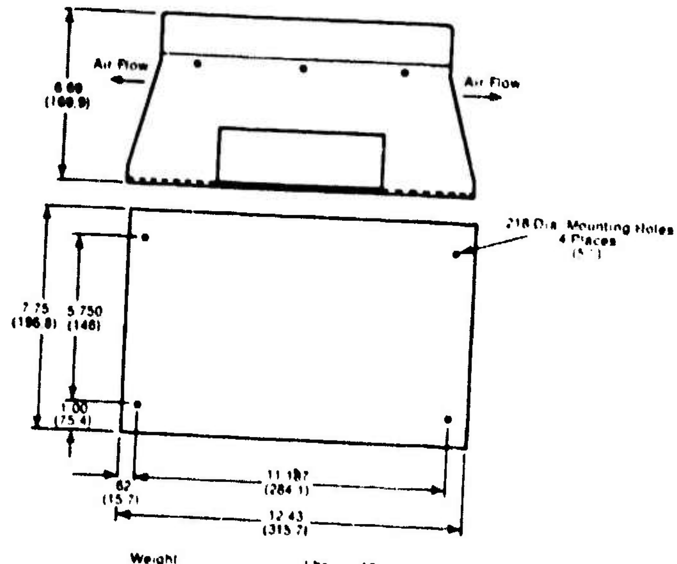
300 SERIES
1.0 KW BRIDGE OUTPUT POWER AMPLIFIER USING SINGLE POLARITY SUPPLY



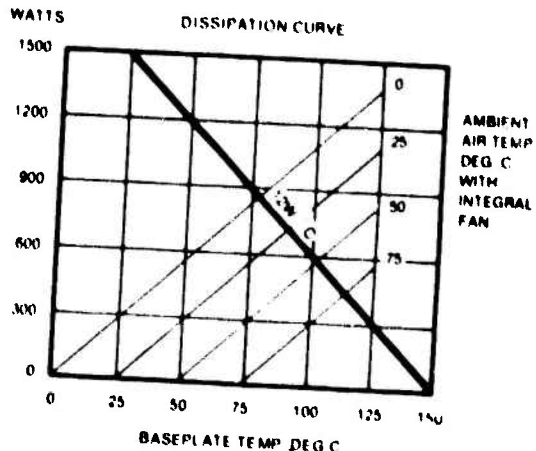
The PA301, 302 and 303 are fast response servo motor drivers suitable for hard continuous duty. The amplifier is designed as a power stage only, requiring a single polarity power supply (plus a low level minus reference) for full bi-polar output. The 301, 302 and 303 are current limited (selectable) and can be specified as current amplifiers.

The output of these amplifiers can be inhibited by removal of the -15 volt reference, thereby permitting a fast, easily programmable shut down.

Heat sinks and fans (115 VAC 60 Hz) are included, providing for a continuous internal dissipation rating of 600 watts, and a peak rating at 25 deg C of 1400 watts. For block diagram and terminal designations see reverse side.



Weight (With Fan & Bracket) Lbs 12 / Kg 5.455



SERIES 300 PERFORMANCE SPECIFICATIONS

	PA-301	PA-302	PA-303
POWER SUPPLY REQUIREMENTS			
DC volts, nominal	35 VDC (± 10%)	+ 50 VDC (± 10%)	50 VDC (± 10%)
DC volts, max.*	+ 60 VDC	+ 60 VDC	+ 60 VDC
Amps, full load*	40 A	25 A	25 A**
Bias supply – volts	- 15 VDC ± 2 V	- 15 VDC ± 2 V	- 15 VDC ± 2
Bias supply – amps	1 mA	1 mA	1 mA
OUTPUT RATING			
Power, watts	1000	1000	1000*
Volts, max with nominal supply	± 25 VDC	± 40 VDC	± 40 VDC
Amps, internally limited	± 40 A	± 25 A	± 25 A*
FULL POWER RESPONSE	1500 Hz	1000 Hz	1000 Hz
GAIN CHARACTERISTICS			
D C gain	20 V/V	20 V/V	20 V/V
Crossover freq.	100 KHz	100 KHz	100 KHz

Note: If optional current gain is specified, gain = 10 amps per volt.

* Combination not to exceed the rated dissipation of the amplifier

** The PA-303 current limit circuit permits up to 50 amps for up to 5 ms. upon each step function demand.

Printed in U.S.A.

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SERIES 300 INPUT CHARACTERISTICS

INPUT IMPEDENCE			
Differential, ohms	10 K	10 K	10 K
Common mode, ohms	210 K	210 K	210 K
INPUT VOLTAGE RANGE			
Absolute max differential	± 15 VDC	± 15 VDC	± 15 VDC
Common mode max	± 10 VDC	± 10 VDC	± 10 VDC
Common mode rejection	60 db	60 db	60 db
TEMPERATURE RANGE			
Base Plate	0 °C to 100 °C	0 °C to 100 °C	0 °C to 100 °C
Operating	0 °C to 50 °C	0 °C to 50 °C	0 °C to 50 °C
Storage	- 30 °C to 70 °C	- 30 °C to 70 °C	- 30 °C to 70 °C

Functionally, the PA-300 series amplifier is divided into the following subunits:

(a) preamplifier stage

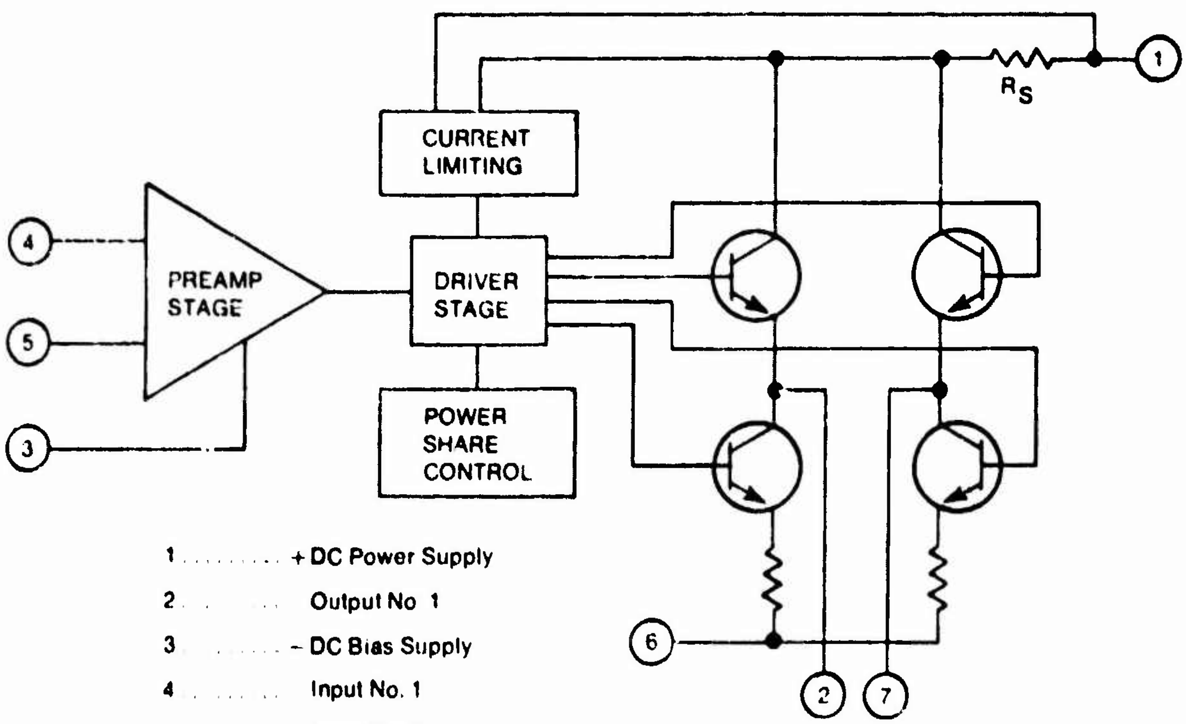
(b) driver stage

(c) power stage

(d) power share control

(e) current limiting

Amplifier block diagram and terminals identification



1 . . . . + DC Power Supply

2 . . . . . . Output No 1

3 . . . . . . - DC Bias Supply

4 . . . . . . Input No. 1

5 . . . . . . Input No. 2

6 . . . . . . Power Ground

7 . . . . . . Output No. 2

Specifications subject to change without notice

TORQUE SYSTEMS INCORPORATED

AN EG&G ROTRON COMPANY

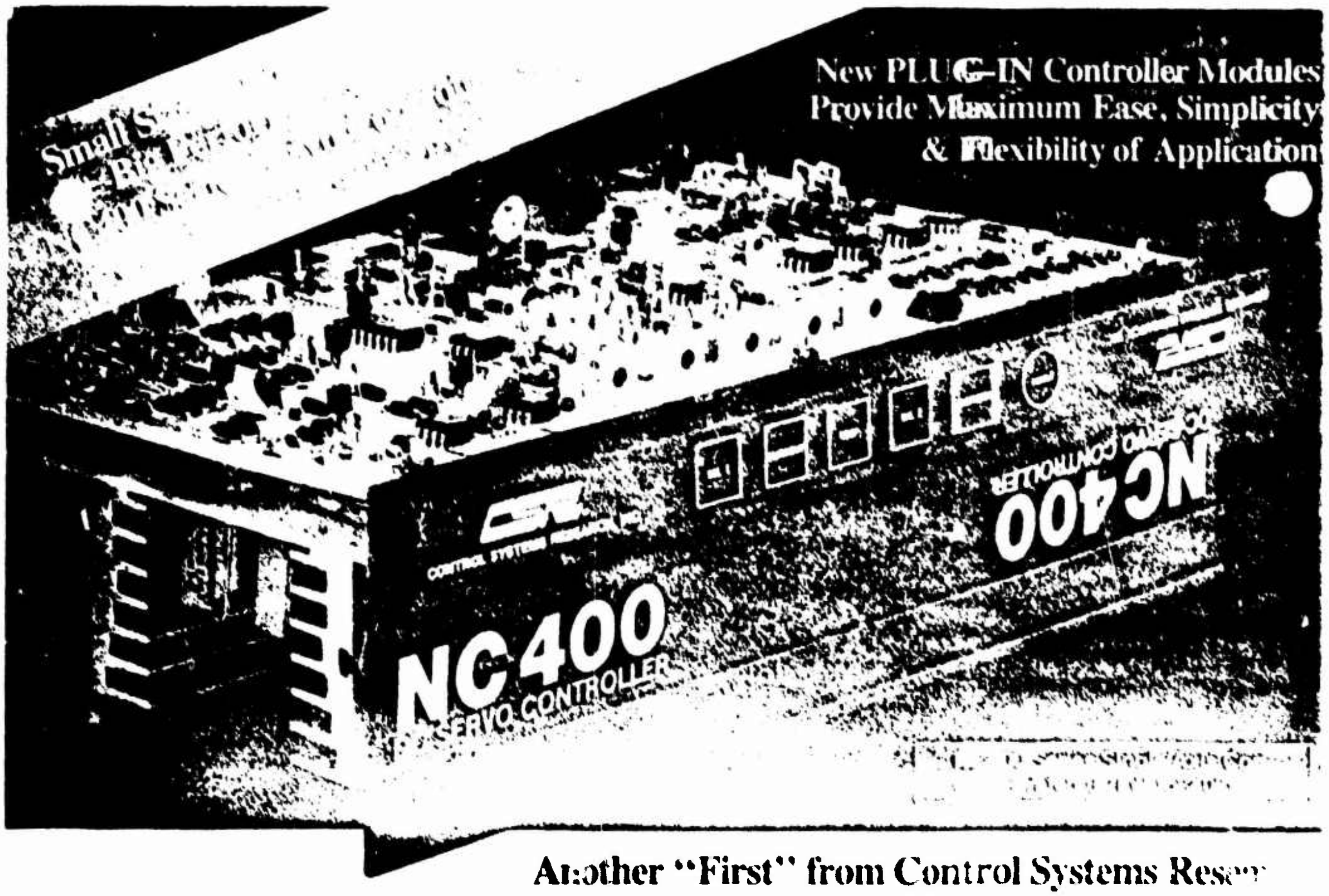
P.O. Box 588
225 Crescent Street
Waltham, Massachusetts 02254
Tel. (617)891-0230 Telex 92-3424

Introduces A Unique Concept...

22A

NC400 Series single-axis module

- Complete controller is a plug-in module, eliminates wiring connections/errors minimizes downtime for controller change/replacement.
- Pulse Width Modulated controller design (patented) assures extremely accurate control of machinery motions & speeds.
- Fully-integrated modular components provide easier, more flexible system application with panel or 19" rack mountings.
- High Performance/Low Cost . . . competitively priced with less accurate & versatile single-phase SCR drives.
- Five Models available for dc servo motors rated from 0.5 to 5.0 hp.



Another "First" from Control Systems Res...

User-Oriented Design

Every feature in NC400 Series controllers has been designed to make the end-user's job as easy and trouble-free as possible. The primary innovation in this new series is its unique packaging concept: **all active components are mounted on simple plug-in modules.** This design permits a complete controller to be installed in or removed from a system — in seconds — **without connecting or disconnecting a single wire.**

The new plug-in design also (1) minimizes downtime if a problem should develop with a controller . . . (2) eliminates the possibility of incorrect rewiring . . . (3) facilitates quick, easy change (if required) in drive capacity or complexity (such as, adding a fourth axis rotary table motion to a three machining center).

Simplified Construction & Mounting

NC400 Series controllers are comprised a plug-in module consisting of two printed circuit (PC) boards. One board contains the low-level **signal electronics** which is common to all NC400 Series controllers; the other PC board contains the appropriate **power electronics** and determines the controller's capacity. Above 2kW output a second plug-in power electronics board is added to the controller.

The complete controller module plugs into a standard mounting assembly, which will accommodate either two NC400 controllers rated up to 2kW each or one unit with up to 5kW capacity. The mounting assembly has a single PC board with connectors for the plug-in servo controllers, and **all system interconnections are made to the mounting assembly** (by means of terminal strips and Faston connectors).

Maximum Reliability

The simplified design and construction of the NC400 controllers greatly enhances system reliability. To assure peak performance under normal operating conditions, each component on the PC Boards is checked with automatic test equipment and then the complete controller is operated at 100% load for 100 hours in a 50°C (122°F) environment. In addition, hand wiring or hand soldered connections are virtually eliminated on these boards.

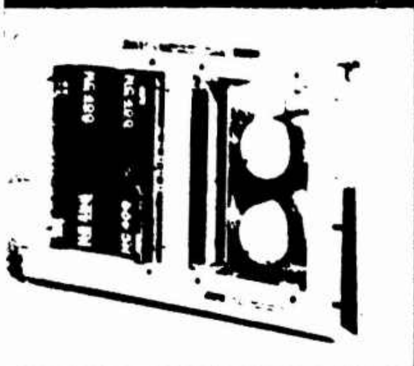
Compact Panel/Rack Mountings

NC400 Series modules can be furnished for either panel or standard 19" rack mounting. Their compact, modular design requires minimal space. In a 19" rack mounting, for example, only 12¼" of panel area are needed to accommodate either two 2kW amplifiers and their power supply or four 2kW amplifiers.

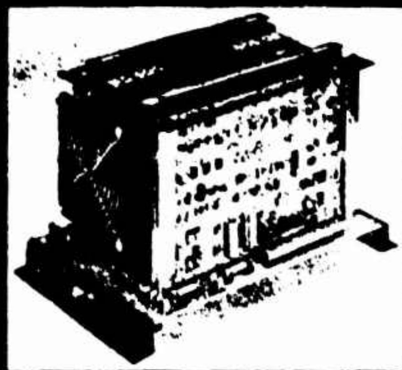
Engineered for Peak Performance

CSR high-performance servo controllers — including the new NC400 Series — are designed not only to be the easiest to use but also to provide the most reliable, most cost effective answer to the requirements of a wide variety of industrial drive applications. All units are transistorized amplifiers which feature CSR's patented **Pulse Width Modulated** (PWM) design concept. When combined with highly efficient, permanent-magnet dc servo motors, these advanced controllers have inherent response capabilities t enable machinery to **operate with optimum efficiency up to the limits of the mechanical systems.**

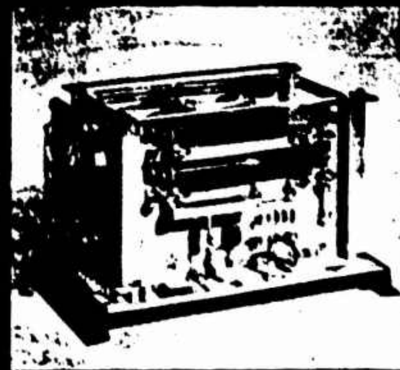
Advanced Technology Assures Optimum Performance in Machine Operations



A 19" rack mounting NC400 System in a two axis plus power supply configuration.



The Two Axis Panel Mounting Assembly allows a variety of NC400 Controller combinations to be installed in a smaller overall panel area than is possible with competitive designs.



Modular Power Supply Assemblies are available for single or three phase operation. An optional regenerative energy dissipation can be quickly installed at any time.

ders in Industrial Motion & Speed Controls

Superior Performance at Low Cost

Not the least of the NC400 Series benefits is the fact that these high-performance transistorized designs are competitive in cost to SCR servo drives that are much less accurate, flexible, and versatile in operation. And price is the only factor on which they are comparable! For high-volume O.E.M. applications, in particular, **the NC400 Series represents the smallest, least costly, and easiest to use line of dc servo controllers available today.**

†U.S. Patents 3,294,981, 4,035,715, and others

System Operating Features

NC400 Series servo controllers feature many built-in user operating and cost-saving benefits that cannot be matched by SCR drives.

Increased Productivity — NC400 Series drives permit higher machine operating speeds and shorter production cycles. The drives are precisely coordinated with both load and machine capabilities, permitting **position loop gains greater than 10 in/min/mil.**

Greater Accuracy/Repeatability — The combination of instantaneous response to input commands or transient load changes and superior speed regulation enables NC400 controllers to enhance machine accuracy and cycle repeatability.

Optimum Motor Performance — NC400 units can provide more torque from a given motor or, in many cases, permit the use of a smaller motor because their low form factor develops full motor capability. In addition, full motor power is available at nearly zero speed, even in a velocity loop, because NC400 controllers provide a very wide speed range and excellent speed regulation.

- **Improved Product Quality** — NC400 units provide an extremely smooth torque output and eliminate the torque pulsations that characterize SCR drives. As a result, NC400 controllers provide significant improvement in the surface finish quality of workpieces and increase normal machine bearing life by their smoother overall operation.
- **No Multi-Axis Cross Talk** — Use of differential input preamplifiers in the NC400 Series eliminates cross talk in multiple-axis applications.
- **No Armature Fuse Problems** — An electronic overload sensing circuit eliminates the need for armature fuses . . . and blown fuse replacement.
- **Built-In Protection** — All NC400 controllers feature complete protection circuits, including two independent over-current (short circuit) detection systems

NC 400 SERIES
SOLID STATE DC SERVO CONTROLLER

C400 - SMALL SIZE. SMALL PRICE, BIG PERFORMANCE

The NC400 Series DC Servo Controllers are a significant step forward in the design of compact, low cost servo controllers. For high volume O. E. M. applications, the NC400 Series are the smallest, easiest to use, least expensive High Performance DC Servo Controllers available today.

Plug In Design
The complete NC400 Series Servo Controller is contained on a printed circuit board that plugs into a simple card rack. All external wiring connects to terminal strips on the card rack. A complete controller can be changed in seconds without removing a single wire—a definite advantage for machine maintenance.

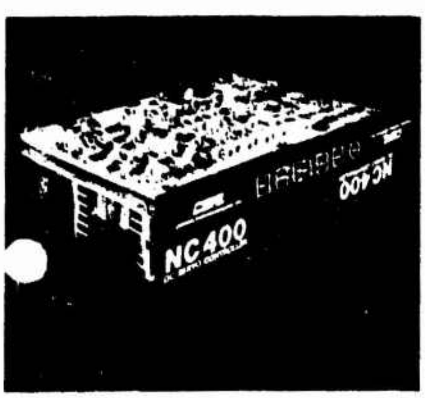
Compact Mounting
Card rack modules for 1 thru 4 axes are available. A 4 axes unit mounts in a 19 inch rack and uses only 12¼ inches (31.1 cm) of panel space. The card rack modules are suitable for either panel mounting or 19 inch rack mounting.

Simple Interfacing
To simplify machine interfaces, the NC400 is provided with differential input preamplifiers, solid state RMS current sensing (I^2t), and a choice of potentiometers or selected fixed resistors for all servo adjustments.

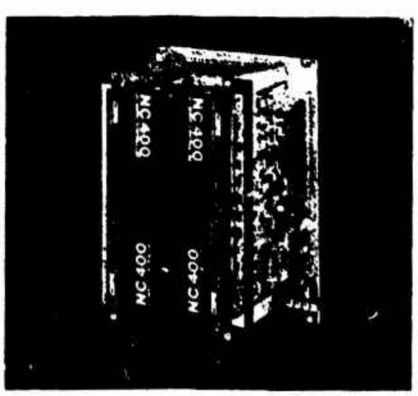
DC Power Supplies
Power supplies are available for single phase or three phase operation from all standard voltages. The power supplies provide 115 VAC and 100 VDC outputs and will operate up to four of the NC421 Controllers (2 kW each). Where necessary, an optional regenerative energy dissipation unit can be added to the power supply.

NC400 SERIES BASIC SPECIFICATIONS

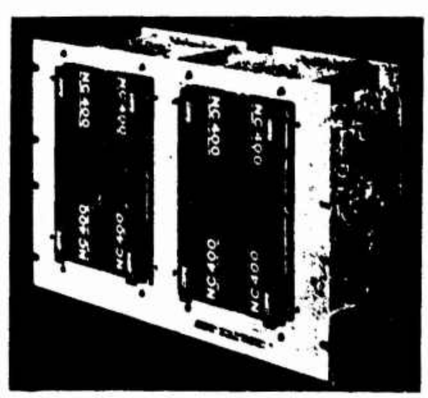
	MODEL NO.	NC407	NC414	NC421	NC435	NC449
1. Maximum Output Voltage	No Load Output (VDC)	±95	±95	±95	±95	±95
2. Output Current (at 50°C)	Peak (A)	15	30	45	75	105
	RMS or Continuous (A)	7	14	21	35	49
3. Nominal Power Output	Continuous (kW)	0.67	1.33	2.00	3.33	4.67
4. Controller Signal Gain	Maximum Gain (±10%) (Ampere Output/Millivolt input)	2.92	5.85	8.77	14.62	20.47
5. Minimum Load Impedance	Motor + Series Inductor (mH)	2.90	1.45	1.00	0.70	0.50
6. AC Input Power						
Amplifier Card	36 VAC, center tapped, single phase, 350 mA					
Card Rack Module	115 VAC, single phase, 1A					
7. DC Input Power	+100 VDC					
8. Frequency Response	DC to 1000 Hz (small signal)					
9. Form Factor	1.01 (at rated output current and specified minimum load inductance)					
10. Weight						
Amplifier Card	3.5 lbs. (1.6 Kg)					
2 Axis Panel Mount	12.5 lbs. (5.7 Kg)					
11. Outline Dimensions						
Amplifier Card	9.19" (233.4 mm) x 3.19" (81.0 mm) x 6.30" (160.0 mm)					
2 Axis Panel Mount	13.62" (345.9 mm) x 8.50" (215.9 mm) x 8.00" (203.2 mm)					



NC 400 SERVO AMPLIFIER



2 AXIS PANEL MOUNT



4 AXIS 19" RACK MOUNT

DC Power Supplies

Available for either single or three phase operation, the modular power supply assemblies for NC 400 units are the same size as the standard mounting assemblies. One power supply will operate several controllers. The power supply will provide up to 6kW continuous power output at a nominal 100VDC. The external transformer, ranging from 1kVA to 6kVA, determines the actual power supply rating.

Optional Shunt Regulator

A regenerative energy dissipation module (Shunt Regulator Unit) can be added to either type of power supply. This solid-state device regulates the dc bus voltage during periods of regeneration. It can be added at any time, since it mounts in integral PC board guides and attaches to the dc bus with only two Faston connectors.

NC400 SERIES BASIC SPECIFICATIONS

	MODEL NO.	NC407	NC414	NC421	NC435	NC449
Maximum Output Voltage	No Load Output (VDC)	±95	±95	±95	±95	±95
Output Current (at 50°C)	Peak (A) RMS or Continuous (A)	15 7	30 14	45 21	75 35	105 49
Nominal Power Output	Continuous (kW)	0.67	1.33	2.00	3.33	4.67

APPROXIMATE OUTLINE DIMENSIONS

	Length	Width	Height
Servo Amplifier Module	9.19"	6.3"	3.19
19" Rack Mounting Assembly	(Depth) 7.38"	19.00	12.25
Standard Mounting Assembly for Amplifiers or Power Supply	13.62"	8.5	8.00

LEADERS IN MOTION CONTROL

CONTROL SYSTEMS RESEARCH, INC.
DIVISION OF CONTRAVES GOERZ CORPORATION
632 FORT DUQUESNE BLVD., PITTSBURGH, PA 15222 PHONE (412) 566-1200 TWX 710-664-4203

HIGH PERFORMANCE

SERVO DRIVES from CONTROL SYSTEMS RESEARCH

PROFITABILITY—Manufacturing operations today continually emphasize increased productivity through automation, higher machine operating speeds and increased machine reliability to maintain or improve profitability. The High Performance Servo Drive from CSR provides a major contribution to increasing machine speeds and productivity.

The High Performance Servo Drive utilizes CSR's patented* Pulse Width Modulated (PWM) servo controller combined with highly efficient and responsive permanent magnet servo motors to produce a drive with the response capabilities to operate a machine to the limits of the mechanical system.

CSR's PRODUCT LINE can provide PWM Servo Controllers to meet nearly any machine requirement. The power capability o' the Servo Controllers ranges from 200 watts to 10 kilowatts continuous output, current output from 10 amperes peak to 200 amperes peak, output voltages from 35 volts to 200 volts.

All CSR Servo Controllers incorporate the same basic design and provide nearly identical features and functions for the user. Most terminal designations and adjustments are the same for all units.

The CSR Servo Controllers are designed to provide the most reliable, easiest to use and the most cost effective solution to demanding drive applications. The High Performance Servo Drive will provide:

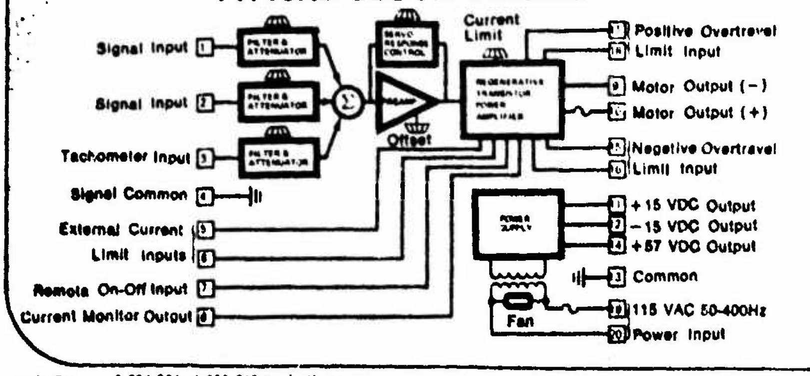
PROFITABILITY THROUGH PERFORMANCE

- **Increased Productivity** through higher speeds, shorter cycle times and drives precisely matched to the load and machine requirements.
- **Better Quality Product** because the extremely smooth torque output gives better surface finish. The high performance gives better speed regulation and increased accuracy along with a significant improvement in repeatability.
- **Obtain Maximum Capability of Machine** by matching the drive speed and torque to the machine requirements. The high response allows operation at position loop gains greater than 10 in/min/mil and provides instantaneous response to a command.
- **Compact Design** requires minimum cabinet space.
- **Simple Installation and Interfacing** to give an operating system in the least amount of time.
- **Designed for Trouble Free Service** with full power, elevated temperature testing of each unit, conservative design, and reliable, low maintenance permanent magnet motors.

STANDARD FEATURES

- **Four Quadrant Regenerative** [illegible]
- **Patented Two-State Modulation** [illegible]
- **Bandwidth to 1000 HZ** [illegible]
- **1.01 Form Factor** [illegible]
- **Speed Range** 5000 [illegible]
- **0.05% Speed Regulation** [illegible] speed [illegible] and changes.
- **Zero Deadband** [illegible] smooth [illegible] and [illegible] speed
- **Adjustable Torque Limiting** with [illegible] to 0-100% of peak torque
- **Adjustable Input Attenuators** provide simple interfacing [illegible] reference or tachometer voltage
- **Total Disable Input** inhibits drive operation with either [illegible] or logic level signal
- **Positive and Negative Disable Inputs** simplify drive [illegible] overtravel limits.
- **Complete Protective Features** include [illegible] overtemperature, short circuit, undervoltage [illegible]
- **Compact Package Design** with four 2 KW amplifiers [illegible] 12.25" (31.1 cm) in a standard 19" rack.
- **Permanent Magnet Servo Motors** require no [illegible] operation and provide full rated torque at stall

TYPICAL BLOCK DIAGRAM



TYPICAL APPLICATIONS

- Feed drives on N/C machine tools
- High speed PC board drilling machines
- Press feeder drives (up to 400 feeds/min)
- Precision speed control in film manufacturing
- Automatic welding feed and spindle drives
- Small AC motor test stands
- High speed positioning using limit switches
- Automated robot axis drives

* U.S. Patents 3,294,981, 4,035,715 and others

NC100 SERIES
SOLID STATE DC SERVO CONTROLLERS

NC100—COMPACT DESIGN FOR COMPACT MACHINES

The NC100 Series DC Servo Controllers are compact, self contained units for low to medium power applications. All units, with the exception of the NC104B, contain DC power supplies and require the application of only AC input power. The power capability of the NC100 Series ranges from 150 watts to 1.4 kilowatts continuous output.

The NC100 Series DC Servo Controllers utilize CSR's patented* Two-State Modulation technique to obtain armature current form factors of less than 1.01 at rated current regardless of the load inductance. The NC100 Series Servo Controllers will drive any motor, even the small disc armature types that have virtually zero inductance, without any additional series inductors. Even a short circuit won't bother the NC100 Series.

All controllers in the NC100 Series have been designed with identical customer connections and identical adjustments. This greatly simplifies wiring and installation in systems requiring different drive types and allows rapid familiarization with the entire NC100 Series.

The Models NC101 and NC102F were specifically designed for use with the 50 watt to 250 watt low inertia, high speed motors with the disc or cup type moving coil armature. These units find many applications in small assembly, printed circuit board drilling, component insertion and computer equipment.

The Models NC104B and NC121F are ideal for either low inertia or conventional permanent magnet motors from 250 watts to 650 watts output. These controllers find many uses in machine tools and automation equipment.

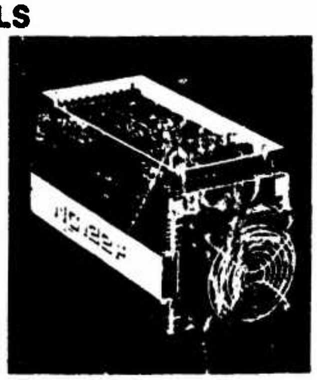
The Model NC122F, with its high voltage output, is an excellent amplifier to use with the larger disc type motors. When used with conventional servomotors, the NC122F is able to operate them to the maximum design speed. This controller is well suited to machine tool and punch press feed drives.

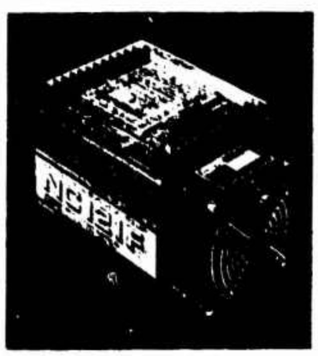
BASIC NC100 SERIES SPECIFICATIONS

	MODEL NUMBER	NC101	NC102F	NC104B	NC121F	NC122F
1. Maximum Output Voltage	No Load Output	35	52	52	52	150
Output Current (at 50°C)	Peak (A) Cont. or RMS (A)	10 5	20 5	35 15	30 10	30 10
3. Nominal Power Output	Cont. (kW)	0.15	0.23	0.63	0.42	1.40
4. Controller Signal Gain	Max. Gain (± 10%) (Ampere Output/ Millivolt Input)	1.95	3.90	6.825	5.85	5.85
5. Input Voltage (50/60 Hz)	Nom. Line ± 10% (VAC) Single Phase	120 or 240	120 or 240	+56 VDC —15 VDC	120 or 240	120/240 3 wire
6. Power Supply	Internal/External	Internal	Internal	External	Internal	Internal
7. Transformer	Internal/External	Internal	Internal	External	Internal	External
8. Weight	Pounds (kg.)	12 (5.45)	17 (7.75)	11 (5.00)	24 (10.91)	20 (9.1)
9. Outline Dimensions	Length In. (mm)	7⅜ (187)	9 (229)	8⅝ (219)	9 (229)	13¾ (349)
	Width In. (mm)	6 (152)	6 (152)	6¼ (159)	6⅝ (168)	6⅝ (168)
	Height In. (mm)	5⅞ (149)	5⅞ (149)	6⅞ (175)	7 9/16 (192)	7⅞ (200)

NC100 SERIES MODELS


MODEL NC102F


MODEL NC122F


MODEL NC121F

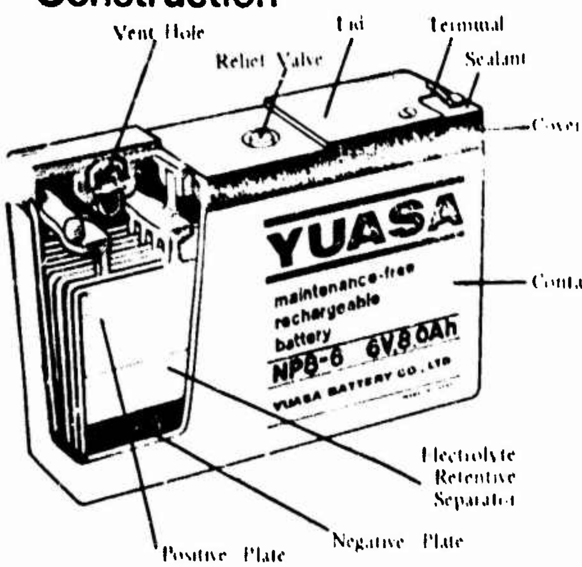

MODEL NC104B

* U.S. Patents 3,294,981; 4,035,715 and others.

YUASA MAINTENANCE-FREE RECHARGEABLE BATTERIES

- These compact and efficient power sources are especially designed for long life, rugged durability, and dependable service.
- Yuasa's unique suspended electrolyte and new venting systems give you the freedom to mount these batteries in any position without fear of leakage or loss of capacity.
- Unparalleled life expectancy in both float and cyclical applications.
- Available at prices competitive with lesser quality batteries.
- Ready for immediate delivery in quantity from our warehouse.

Construction



For further technical information or assistance in choosing the proper battery for your application, contact your nearby Yuasa sales representative, or call us direct.

YUASA BATTERY (AMERICA) INC.
8108 Freestone Avenue
Santa Fe Springs, California 90670
(213) 698 2275 Telex 69 6272

Limited warranty

Each Yuasa NP Series battery which is sold is warranted against defects in workmanship and materials for a period of one year from the date of manufacture. Under this warranty, our obligation ... is limited to the repair or replacement of the battery. Such repair or replacement will be FOB our warehouse in Santa Fe Springs, California or other designated location that Yuasa Battery (America) Inc., may designate. Such repair or replacement will be made only after our examination determines that said battery is defective in material and/or workmanship. We exempt from any warranty claim any battery which has been subjected to misuse, abuse, altered, or any battery that may have been repaired or attempted to be repaired by other than Yuasa Battery (America) Inc.

THIS WARRANTY MADE IN LIEU OF ALL OTHER WARRANTIES WITH RESPECT TO THE ... COVERED HEREBY AND THERE ARE NO WARRANTIES, WHETHER EXPRESSED OR IMPLIED OF MERCHANTABILITY OR OTHERWISE ... THE WARRANTY EXPRESSLY STATED ... REMEDY SET FORTH HEREIN SHALL BE THE EXCLUSIVE REMEDY OF ANY PURCHASER ... SPECT TO ANY DEFECTIVE PRODUCT. UNDER ... CIRCUMSTANCES SHALL WE BE LIABLE FOR ANY INJURY, LOSS, DAMAGE, OR EXPENSE SUFFERED OR INCURRED WITH RESPECT TO ANY DEFECTIVE PRODUCT.

OUR REPRESENTATIONS ARE BASED ON CONSERVATIVE ENGINEERING PRACTICES, AND EVERY ATTEMPT HAS BEEN MADE TO ELIMINATE OVERSTATEMENT OF OUR BATTERIES' SPECIFICATIONS OR PERFORMANCE.

... Inc.
... Executive Blvd
Columbus Ohio ...
614 ...

YUASA MAINTENANCE-FREE RECHARGEABLE BATTERIES

Common specifications

Operating temperature ranges
Charge: -20°C to 50°C (5°F to 122°F)
Discharge: -40°C to 50°C (-40°F to 122°F)
Storage: -40°C to 60°C (-40°F to 140°F)

Life expectancy
Standby use: 4 to 5 years
Cyclic use: 250 to 1200 cycles

Sealed construction
Can be operated, charged or stored in any position.

Terminals
.187w X .032t male standard, .250 optional

Note: Also available — NP24-12 with bolts; NP4-6 with wires.

Charging parameters at 25°C

Standby use:
maximum charging current . . . . .25% of rated capacity
charging voltage** . . . . .2.25 to 2.30 volts per cell

Cyclic use:
maximum charging current . . . . .25% of rated capacity
charging voltage** . . . . .2.43 to 2.50 volts per cell

When using a constant voltage, current limited charging system in the temperature range of 5° to 40°C (41° to 104°F), temperature compensation is not necessarily needed. Out of the above temperature ranges, temperature compensation of -4mv/°C/cell is required.

Discharge rates

	20 hr.	10 hr.	5 hr.	3 hr.	1 hr.
*NP1.2-6 6v1.2AH	0.06A	0.11A	0.20A	0.30A	0.70A
*NP2.6-6 6v2.6AH	0.13A	0.24A	0.44A	0.66A	1.60A
*NP4-6 6v4AH	0.20A	0.37A	0.68A	1.00A	2.40A
*NP4.5-6 6v4.5AH	0.22A	0.42A	0.76A	1.10A	2.70A
*NP6-6 6v6AH	0.30A	0.56A	1.02A	1.50A	3.60A
*NP8-6 6v8AH	0.40A	0.74A	1.36A	2.00A	4.80A
*NP10-6 6v10AH	0.50A	0.93A	1.70A	2.50A	6.00A
NP1.9-12 12v1.9AH	0.09A	0.18A	0.32A	0.50A	1.10A
NP2.6-12 12v2.6AH	0.13A	0.24A	0.44A	0.66A	1.60A
NP6-12 12v6AH	0.30A	0.56A	1.02A	1.50A	3.60A
NP24-12 12v24AH	1.20A	2.23A	4.08A	6.85A	14.40A

*All 6v cells are available in 2 cell assemblies for 12v applications.

Dimensions

	length		width		height	
	mm.	ins.	mm.	ins.	mm.	ins.
NP 1.2-6	97	(3.82)	25	(.98)	50.5	(1.99)
NP 2.6-6	135	(5.31)	35	(1.38)	59	(2.36)
NP 4-6	70	(2.76)	46.5	(1.83)	104.5	(4.11)
NP 4.5-6	151	(5.95)	33.5	(1.32)	95.5	(3.76)
NP 6-6	151	(5.95)	34	(1.33)	96	(3.78)
NP 8-6	151	(5.95)	50	(1.97)	95.5	(3.76)
NP 10-6	151	(5.95)	50	(1.97)	96	(3.78)
NP 1.9-12	178	(7.01)	34	(1.33)	59	(2.36)
NP 2.6-12	195	(7.68)	47	(1.85)	70	(2.76)
NP 6-12	151	(5.95)	65	(2.56)	96	(3.78)
NP 24-12	166	(6.54)	175	(6.89)	125	(4.92)

EAGLE PICHER

SINCE 1843

Carefree

RECHARGEABLE BATTERY

CF6V30 SPECIFICATIONS

Nominal Open Circuit Voltage	6.36 volts
Nominal Working Voltage	5.94 volts
Nominal Capacity at 68°F:	
20 Hour Rate (1.40 Amperes to 5.25 volts)	28.0 ampere hours
10 Hour Rate (2.60 Amperes to 5.10 volts)	26.0 ampere hours
5 Hour Rate (4.60 Amperes to 4.95 volts)	23.0 ampere hours
1 Hour Rate (16.0 Amperes to 4.50 volts)	16.0 ampere hours
Physical Size ± .05 Inches	
Length	6.25 inches
Width	3.35 inches
Height	6.50 inches
Height (Including terminals)	6.75 inches
Volume (Excluding terminals)	136.1 cubic inches
Weight	11.5 pounds
Energy Density (20 Hour Rate)	1.23 watt hrs./cu. in.
(20 Hour Rate)	14.6 watt hrs./lb.
Operating Temperature Range:	
Discharge	-60°F to + 140°F
Charge	0°F to + 120°F

Recharging Methods:

Float Charging: Constant Potential Source of 6.75 to 6.90 volts continuously.

Routine Charging: Constant Potential Tapered Charge Source of 7.35 to 7.50 Volts with a maximum Charging Current of 3.00 Amperes.

Terminal: Standard is AMP No. 42484-2 Tin Plated Brass, .032 Stock x .25 Wide. Mates with ETC No. AA-8140 For .032 x .25 TAB or Equal. Special Terminals Available upon request.

Case Material: High Impact Polystyrene, Black.

The specifications on this page may be changed by Eagle-Picher Industries, Inc. without notice.

MANUFACTURED BY
EAGLE-PICHER INDUSTRIES, INC.
ELECTRONICS DIVISION
COMMERCIAL PRODUCTS DEPARTMENT
P.O. BOX 130 • SENECA, MISSOURI 64865
PH. (417) 776-2258 • TWX# 910-774-4508

Carefree / Carefree magnum

STANDARD RECHARGEABLE BATTERIES

Carefree O.E.M. PRICE SCHEDULE — Effective March 1, 1978

BATTERY NO.	VOLTAGE	A.H. AT 20 HR. RATE	QUANTITY and COST PER BATTERY 1-9	10-49	50-99	100-499	500-999	1000+
CF2V2.5	2	2.5	$ 7.63	$ 7.30	$ 6.57	$ 5.86	$ 5.28	$ 4.46
CF2V5	2	5	6.41	6.12	5.52	4.91	4.42	3.70
CF2V30	2	28	14.62	13.98	12.60	11.20	10.08	8.40
CF6V½	6	.45	6.02	5.77	5.22	4.63	4.18	3.48
CF6V1	6	0.9	8.46	8.08	7.31	6.51	5.85	4.88
CF6V2.6	6	2.6	12.82	12.26	11.07	9.85	8.87	7.42
CF6V4.5	6	4.5	13.67	13.04	11.75	10.46	9.43	7.90
CF6V8	6	8	16.00	14.80	13.88	12 34	11.10	9.25
CF6V15	6	15	24.12	23.03	20.86	18.57	16.66	13.92
CF6V30	6	28	35.90	34.24	30.90	27.60	24.90	20.75
CF6V40	6	40	65.75	55.10	50.54	44.84	42.28	38.00
CF8V6	8	6	21.10	20.17	18.20	16.21	14.85	12.21
CF12V½	12	.45	12.90	12.38	11.19	9.92	8.98	7.46
CF12V1	12	0.9	17.09	16.35	14.77	13.14	11.82	9.90
CF12V1L	12	0.9	17.09	16.35	14.77	13.14	11.82	9.90
CF12V1.5	12	1.5	19.41	18.56	16.75	14.90	13.37	11.21
CF12V2.6	12	2.6	26.21	25.05	22.61	20.12	18.13	15.19
CF12V5L	12	5.0	24.20	23.15	20.90	18.58	16.75	14.00
*CF12V5PP	12	5.0	36.56	34.95	31.55	28.10	25.27	21.16
CF12V8	12	8	32.87	31.35	28.50	25.27	22.80	19.00
CF12V15	12	15	48.24	46.06	41.92	37.14	33.32	27.84
CF12V20	12	20	58.00	53.85	44.25	42.00	39.00	35.90
CF12V30	12	28	74.04	70.62	63.75	56.90	51.36	42.80
CF12V30L	12	28	76.04	72.62	64.55	57.90	52.55	45.00
CF18V1	18	0.9	25.50	24.36	21.98	19.57	17.65	14.75
CF24V20	24	20	117.40	113.75	94.00	85.00	82.00	73.40
CF24V30	24	28	153.10	146.00	129.60	114.70	106.20	[illegible]8.50

*CF12V5PP comes with charger

Carefree magnum

BATTERY NO.	VOLTAGE	A.H. AT 20 HR. RATE	QUANTITY and COST PER BATTERY 1-9	10-49	50-99	100-499	500-999	1000+
CFM6V33	6	33	37.70	35.95	32.68	28.98	26.15	21.79
CFM12V33	12	33	77 75	74.15	67.41	59.77	53.93	44.94

TERMS:

5% DISCOUNT 15 DAYS: NET 30 DAYS SUBJECT TO CREDIT APPROVAL. ALL INVOICES OVER 30 DAYS ARE SUBJECT TO A 1.5% PER MONTH SERVICE CHARGE ON PAST DUE BALANCE WHICH IS AN ANNUAL RATE OF 18%.

D-70

Prices do not include Federal Excise, State, or Local Sales or Use Taxes.

F.O.B.
ALL ITEMS SHIPPED F.O.B., SENECA, MISSOURI, FREIGHT COLLECT

EAGLE PICHER

EAGL[illegible]R INDUSTRIES, INC.
Co[illegible] [illegible]oducts Department

P.O. Box 130, [illegible] Mo. 64865
Telephone (4[illegible] [illegible]58

DESCRIPTION

The unique design of the Gates Energy Cell overcomes many of the former limitations of the lead-acid system. At the same time, it retains the low cost, reliability, ruggedness and long life which have always been assets of the lead-acid battery. The cell is truly sealed— no acid, acid vapor or water loss— and incorporates recombination of gases within a starved electrolyte system. This unique maintenance-free rechargeable lead-acid cell is constructed with thin, spirally-wound, pure lead plates which result in low impedance, low corrosion and long life. The self-resealing safety valve will vent under abusive overcharge conditions at an internal pressure of about 50 psi.

- Can be charged or discharged in any position.
- Use constant current or constant voltage charging.
- The same cell can be used for fast-cycling or long-term float applications.
- Low internal impedance allows very high discharge currents.
- No loss of electrolyte during normal overcharging.
- Excellent mechanical and vibrational strength.
- Absolutely no "memory" effects.
- No damage due to cell reversal.
- The metal can is electrically isolated preventing accidental shorting.
- Fewer cells per battery for lower battery cost and better reliability.
- Cells can be paralleled for additional capacity.
- Can be used safely in proximity of electronic circuitries.

TYPICAL SPECIFICATIONS (T_A=25°C)

Nominal cell voltage	2.0V
Capacity rating	
20 hour rate (1.25A)	26Ah
10 hour rate (2.50A)	25Ah
1 hour rate (25.0A)	20Ah
Cell Power Rating	
Peak Power (at 600A)	600W
Energy/unit volume (at C/10 rate)	1.47 W-h/in³ 0.09 W-h/cm³
Energy/unit weight (at C/10 rate)	14 W-h/lb 31 W-h/kg

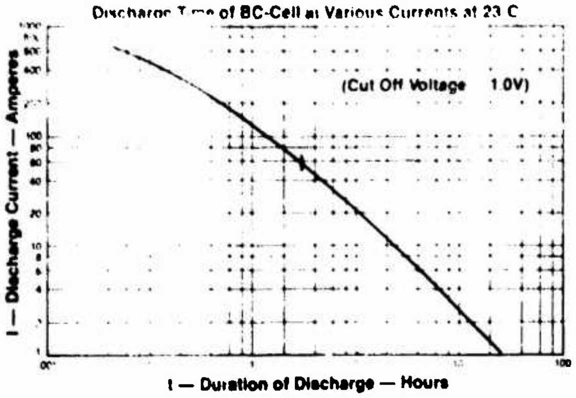
Cell Temperature Range	
Storage	−65°C to +65°C
Discharge	−65°C to +65°C
Charge	−40°C to +65°C
*Internal Resistance (max) (Charged Cell)	$2.2 \times 10^{-3}\Omega$
Cell Charging	
Constant Voltage (Cyclic)	2.40 — 2.60V
(Float)	2.30 — 2.40V
Constant Current (Float) (max)	C/500 rate

*Measured on Hewlett-Packard 4328A milliohm meter

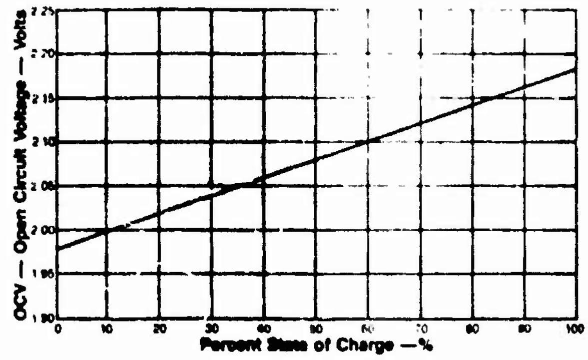
Shown 43% actual size.

2V, 25.0Ah sealed rechargeable "BC" cell

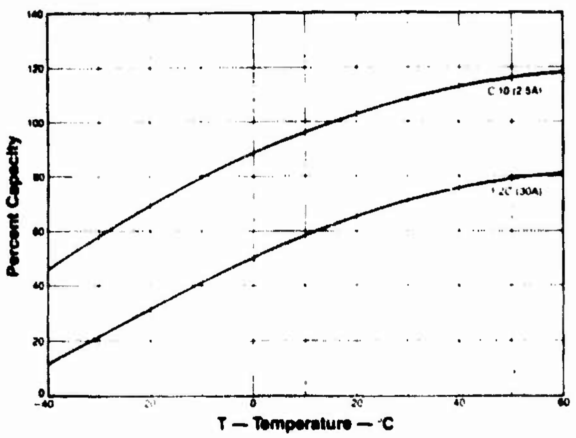
Discharge Time of BC-Cell at Various Currents at 23 C



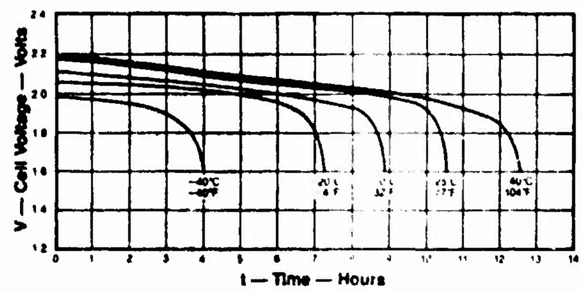
Discharge Characteristics. Based on data from standard production, 90% of all cells produced by GEP meet or exceed these discharge characteristics. New cells must be cycled or floated appropriately before full rated capacity, as shown on this curve, is reached.



State of Charge. This curve of OCV vs state of charge is accurate within 20% of the rated capacity of the cell being measured if it has not been charged or discharged within the past 24 hours. The accuracy increases to 5% if the cell has not been charged or discharged within the past five days.



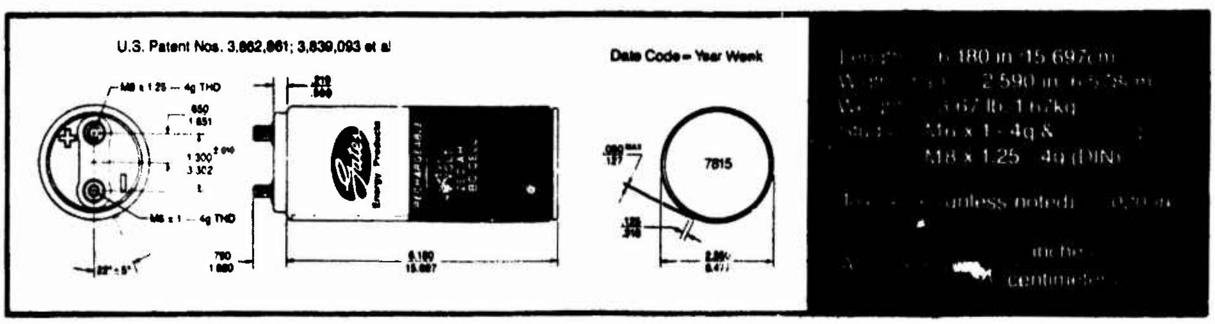
Temperature Characteristics. The graph illustrates the capacity available in the cell as a function of temperature at two different discharge rates.



Voltage Regulation. The voltage regulation of the Gates cell is equal to or better than any other commercially available system. Typical curves shown.

Leaving the Gates Energy Cell connected to a load for a long period of time after it has been discharged may cause difficulties in recharging and or reduce cell life. The cell should be put on open circuit or recharged soon after the discharge is completed.

Note: When assembling cells into batteries nut torque must not exceed 35 in.-lb./3.95 N·m.



Gates Energy Products, Inc.

Energy Products

1050 S. Broadway • Denver, CO 80217 • (303) 744-4806

APPENDIX E

SENSOR VENDOR DATA

Crosswind Velocity Sensor

MODEL 201

- Fully Qualified to Military Vehicle Environment
- High Reliability
- No Moving Parts
- Manual and Automatic BITE
- Range is 0-20 m/s (0-45 MPH)
- Accuracy is $\pm$ .5 m/s $\pm$ 10%
- Weight is 5.7 kg (12.5 lbs.)
- Dimensions are 8.25 x 56 cm (3.25 x 22 inches)
- Power Requirements are +15V DC, -15V DC,

  +18 - 30V DC

The Model 201 uses the IONFLO® technique to sense wind velocity. This technique requires no moving parts.

Although the fundamental principles involved in this method are quite sophisticated, TSI has reduced the mechanization of the function to the point that performance is dependent primarily upon a precise mechanical configuration of the sensing head.

TSI's Model 201 Crosswind Velocity Sensor has undergone extensive reliability and performance testing on the XM-1 Battle Tank.

from tsi®

TSI Incorporated

HIGH RELIABILITY

Throughout all phases of EDM testing and qualification, the Model 201 has yet to experience a failure.

Maintenance:

To date total field maintenance has consisted of cleaning the unit by a simple washing process.

FSED modules are fitted with a cleaning hole which permits cleaning by squirting tap water from a squeeze bottle into the hole.

BITE

Automatic self test provides a "fail" signal for malfunctions of vehicle power, high voltage supply, Ion Emitter or sensor plate.

Manual self test, when externally triggered, verifies correct assembly operation

This BIT capability provides fault isolation to the assembly with a 90% confidence level.

ADAPTABILITY

Available in ranges to 80 meters per second linear or non-linear outputs.

Technical literature available upon request.

TSI Incorporated
500 Cardigan Road
P. O Box 3394
St. Paul, MN 55165

CIC

ALTITUDE TRANSDUCERS

MODEL 8000

Models 8000 and 8200 altitude transducers provide accurate measurement of altitude ranging from −2000 to 100,000 feet above sea level, for use in aircraft indication and flight control. LVDT sensing of aneroid pressure diaphragm motion combined with sophisticated solid-state circuitry provides reliable high-level DC outputs suitable for interfacing with any system.

These transducers are available with various altitude ranges and output voltage gradients, and can be modified to suit any required pressure port, connector, or outline configuration. Supplementary internal circuitry can be supplied to provide Altitude Hold or rate-of-climb outputs.

MODEL 8200

Typical Specifications

Alt. Range −1,000 ft. to	35,000 ft.	50,000 ft.
Accuracy – % Alt.	±.25% +20 ft.	±.4% +40 ft.
Output – Full Scale	10 VDC	10 VDC
Resolution	1 ft.	3 ft.
Repeatability	10 ft.	20 ft.
Hysteresis	10 ft.	20 ft.

Environmental

Temperature Range:	−55°C to +85°C
Temperature Effect:	0.015% F.S. per °C
Vibration:	55 – 500 Hz
Acceleration Effect:	0.02% F.S. per g @ 0 ft.

[DUCERS

Model No.	Price for Quantity of 10	100	1000
8000	$850.	$735	$685
8200	Slightly cheaper		

ɿ transducers provide high-level DC ed airspeed ranging from 30 knots .VDT sensing a pressure diaphragm ˈerence between applied static and

/oltage gradients and in mechanical transducers can be supplied with provides rate-of-change of airspeed arning systems.

MODEL 8300-1

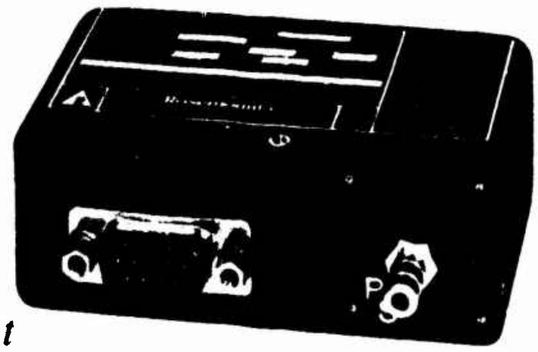
Airspeed Range	30-200 kt.	50-450 kt.
Accuracy		
Below 100 kt.	4 kt.	4 kt.
100 – 200 kt.	1.5 kt.	1.5 kt.
% IAS above 200 kt.	–	0.5% + 1.5 kt.
Output	0-10 VDC	0-10 VDC

Environmental

Temperature Range:	−55° to 85° C
Temperature Effect:	0.015% F.S. per °C
Vibration:	55 – 500 Hz
Acceleration Effect:	0.02% F.S. per g

PRODUCT DATA SHEET 2229

MODEL 1241M
MINI BAROMETRIC
ALTITUDE TRANSDUCER



Four standard altitude ranges

High accuracy high level DC output

Continuous resolution

INTRODUCTION

Rosemount's Model 1241M Mini Altitude Transducer is designed to provide a high level DC output signal proportional to barometric altitude for low altitude aircraft or mobile position location systems, where a precision air data measurement is required at a reasonable cost, and where size and weight must be kept to a practical minimum. The transducer is a solid state, flight proven design which operates over altitude ranges from −1000 to 15,000 feet.

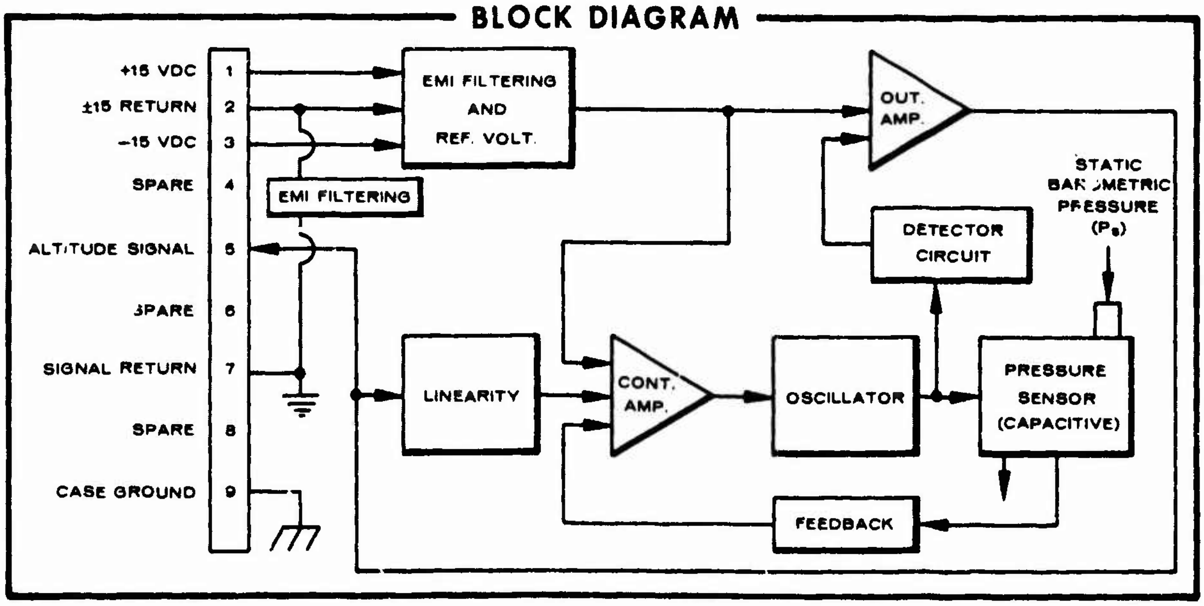
Rosemount's patented* capacitive pressure sensing capsule is used in the transducer and provides infinite resolution, superior repeatability and negligible hysteresis. These three parameters determine the inherent relative accuracy of the transducer and, therefore, establish the sensitivity and responsiveness of the basic altitude reporting system. The excellent relative accuracy of the Model 1241M Transducer ensures the maintainability of level flight when altitude hold is initiated, and that the system will return precisely to a pre-established altitude after completion of a programmed maneuver.

The transducer uses established reliability parts to ensure a long, reliable operating life.

TYPICAL APPLICATIONS

- Mini RPV Flight/Altitude Control
- Manned Position Location Systems
- Low Altitude Aircraft Flight Control

BLOCK DIAGRAM



Rosemount

*Protected by the following U.S. Patents: #3,195,028; 3,271,669 and 3,318,153.

THEORY OF OPERATION

Static barometric pressure (P_S) is sensed by Rosemount's patented capacitive pressure sensing capsule. The capsule consists of a stainless steel case which houses a capacitor plate positioned directly adjacent to a "free edge" diaphragm. This "free edge" design allows for a low stress, hinge-like deflection of the diaphragm, which is the reason for the superior hysteresis, repeatability, and resolution performance. The chamber on one side of the diaphragm is exposed to the static pressure, while the chamber on the opposite side is evacuated and sealed off, resulting in a diaphragm deflection proportional to the barometric absolute pressure.

The capacitance change generated by the pressure capsule as barometric pressure changes is converted to a high level DC voltage by the signal conditioning electronics shown in the block diagram. A controlled product oscillator, consisting of a control amplifier, a feedback network, and an oscillator, excites the pressure sensing capsule with a closely controlled AC voltage. The detector develops a DC signal proportional to the excitation and capacitance of the capsule. The reference voltage circuit regulates the oscillator and other circuits. The detector signal is amplified by the output amplifier to produce the 0–10 VDC output capability of the transducer. Part of this output signal is fed back through a linearizing network which linearizes the output proportional to altitude.

Design Specifications

ALTITUDE RANGES

The Model 1241M provides a high level DC output signal proportional to the following barometric altitude ranges:

MODEL CODE	ALTITUDE RANGE
1241M1	−1000 to 10,000 feet
1241M2	S.L. to 10,000 feet
1241M3	−1000 to 15,000 feet
1241M4	S.L. to 15,000 feet

OUTPUT VOLTAGE

The Model 1241M Altitude Transducer is available in either a 0.5 millivolt/foot output voltage gradient or a 0 to 10 VDC output over the desired altitude range. (See Ordering Information.)

OVERPRESSURE RANGE

The transducer will withstand static pressures (P_S) of 150% of full scale operating pressure without damage or performance degradation, (−12000 to 50000 feet).

Performance Specifications

RELATIVE ACCURACY

Relative accuracy is defined as the root-sum-square total of resolution, repeatability, and hysteresis errors. It defines the accuracy with which the transducer can hold or maintain constant altitude, irrespective of the absolute accuracy of the transducer. The relative accuracy of the 1241M is listed below.

BAROMETRIC ALTITUDE (FEET)	RELATIVE ACCURACY 10,000 Ft. Range	15,000 Ft. Range
S.L.	±5.1 feet	±6.25 feet
10,000	±6.9 feet	±8.5 feet
15,000	N.A.	±9.9 feet

OPERATING ACCURACY

Operating accuracy includes resolution, repeatability and hysteresis errors, as well as nonlinearity, calibration tolerances, and the error due to ambient temperature variations over the calibrated temperature range.

The altitude output operating error band limits for the model 1241M Altitude Transducer are ±50 feet, with respect to an ideal straight line output as shown in Figure 1. For reference, the altitude recognition curves of the transducer are also shown in Figure 1. These curves illustrate the nominal departure of the output signal in feet with respect to a straight line drawn between ideal endpoints.

TIME CONSTANT

The output signal reaches 63% of its final value within 30 milliseconds after application of a step pressure change.

WARMUP TIME

The transducer is operational at turn-on. However, a five minute warmup time, to allow for equipment stabilization, is recommended prior to commencement of quality assurance testing.

POWER SUPPLY EFFECT

The output signal change, for a change in the ±15 VDC power supply voltage, does not exceed ±0.015% of full scale output per 1% change in the ±15 VDC power supply voltage.

ACCELERATION AND VIBRATION SENSITIVITY

Acceleration and vibration sensitivity of the altitude output signal in the most sensitive axis does not exceed ±9 feet/g at sea level and ±15 feet/g at 10,000 feet, (equivalent to ±0.03% of 16 psia full scale pressure per g).

Rosemount Inc.
P O BOX 35129
MINNEAPOLIS, MINNESOTA 55435 PHONE (612) 941 5560
TWX 910 576 3103 TELEX 29 0183 CABLE ROSEMOUNT

PRICE LIST P2229
EFFECTIVE: 1 MARCH 1976
00.00.00.00

MODEL 1241M ALTITUDE TRANSDUCER

MODEL 1241M	ALTITUDE TRANSDUCER	BASE $650

CODE	CALIBRATED ALTITUDE RANGE	ADD
1	−1,000 to 10,000 Feet	N.C.
2	S.L. to 10,000 Feet	N.C.
3	−1,000 to 15,000 Feet	N.C.
4	S.L. to 15,000 Feet	N.C.

CODE	CALIBRATED AMBIENT TEMPERATURE RANGE	ADD
A	−20°C to +50°C	N.C.
B	−55°C to +71°C	$30

CODE	OUTPUT GRADIENT/VOLTAGE	ADD
1	0.50 mVDC Per Foot	N.C.
2	0 to +10 VDC Output Over the Calibrated Alt. Range	N.C.

1241M	2	A	1	← PRICING EXAMPLE	$650

Mating Connector, M24308B-1 (Cannon P/N DEMM9S)
Rosemount P/N C11120-0001 . . . . .$10.00

QUANTITY DISCOUNT SCHEDULE

QUANTITY	PRICE
1–5	Base Price
6–11	Base Price Less 5%
12–24	Base Price Less 10%
25 and Up	Consult Factory

ORDERING INFORMATION

Specify complete model number.
Specify method of shipment.

SHIPPING INFORMATION

Average shipping weight is two (2) pounds.

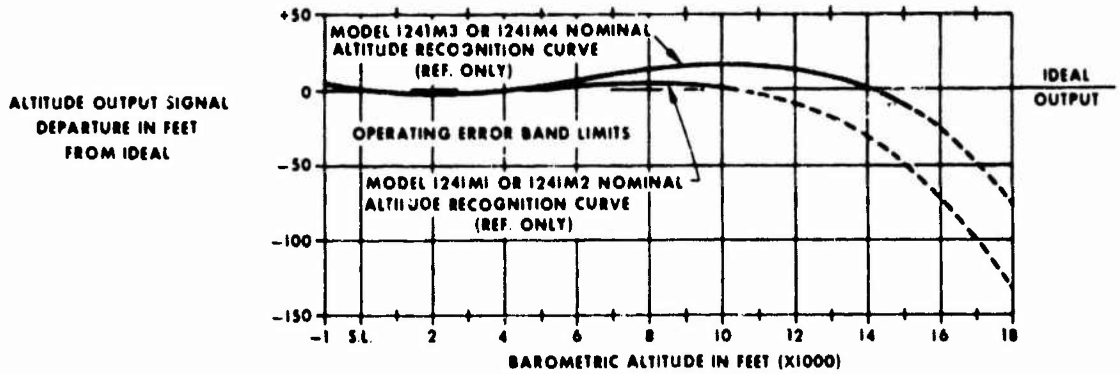
WARRANTY

Warranty on the original purchase against defects in material and workmanship is for a period of one year from date of shipment.

GENERAL NOTES

The above prices are effective with date of issue and are subject to change without notice.
All prices are F.O.B. our plant at Minneapolis, Minnesota.
The above prices are exclusive of all sales and use taxes.
Prices are for sales and shipment within the Continental U.S.A. (excluding Alaska) and do not allow for export packaging.

FIGURE 1
OPERATING ACCURACY



Electrical Specifications

INPUT POWER The transducer operates from a +15 VDC +10% supply at a nominal input current of 0.025 amperes.

OUTPUT CURRENT CAPABILITY The output signal will supply current to load impedances of 10,000 ohms or higher.

OUTPUT IMPEDANCE Less than 10 ohms.

OUTPUT SIGNAL NOISE The altitude signal noise is typically 10 millivolts peak-to-peak. The maximum noise signal is 20 mV peak-to-peak and is limited to the upper portion of the altitude range.

INPUT-OUTPUT ISOLATION

The 15 VDC power return and the output signal return are internally connected. It is recommended that the 15 VDC return be externally connected to case ground during testing and in actual service to reduce output signal noise to a minimum.

INSULATION RESISTANCE Insulation resistance between all signal and power leads tied together and case ground shall be 100 megohms minimum at 50 VDC.

Environmental Specifications

OPERATING TEMPERATURE RANGE

The transducer is calibrated to meet the performance specifications, defined herein, while operating over the ambient temperature range of −20° to +50°C or −55° to +71°C. (See Ordering Information.)

VIBRATION 10 g's, 5 to 2000 Hz.

HUMIDITY Up to 95% relative humidity.

SHOCK The transducer shall withstand a 15 g, 11 millisecond half sine shock pulse while operating.

Mechanical Specifications

FINISH The transducer's aluminum enclosure is black anodized per MIL-A-8625. The mounting plate is Iridited † per MIL-C-5541, Class 3.

WEIGHT Transducer weight is 6.0 ounces maximum.

MOUNTING Mounting of the transducer may be accomplished by use of the four mounting holes, (see Dimensional Drawing).

NAMEPLATE INFORMATION Each transducer shall be marked with the following minimum information:

- Model Number
- Altitude Range
- Input Power
- Serial Number
- Output Signal
- Pin Designations

MECHANICAL INTERFACE See Outline Dimensional Drawing.

Quality Assurance

GENERAL

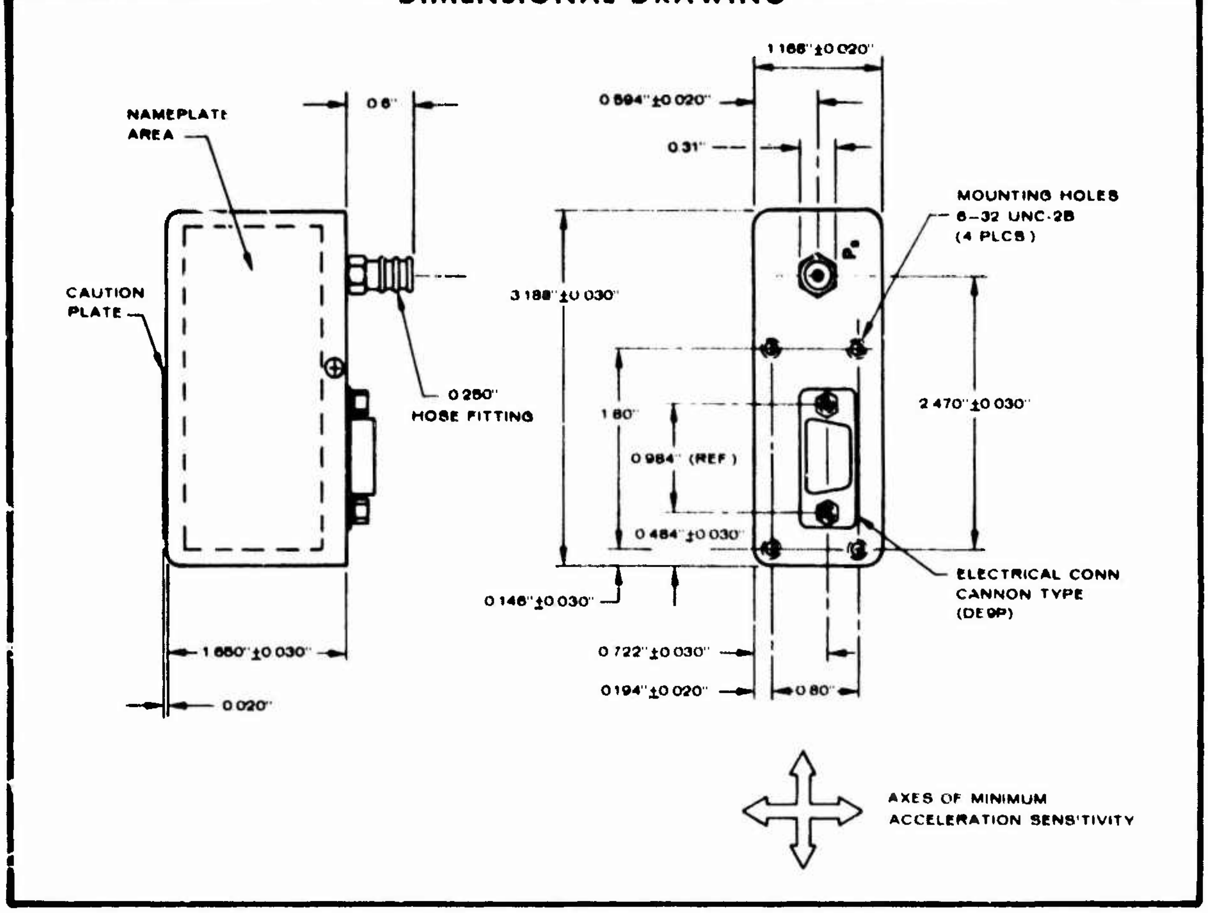
Rosemount's quality control system conforms to MIL-Q-9858A, MIL-C-45662A, NASA Publication NPC 200-3, and Federal Aviation Regulations parts 21 and 37.

ACCEPTANCE TESTING

Each transducer is mechanically and electrically inspected for good workmanship and proper operation. Calibration data is recorded at a minimum of five points at room temperature. A copy of the calibration data is provided with each transducer.

† IRIDITE is a trademark of the Richardson Co.

DIMENSIONAL DRAWING



ORDERING INFORMATION

MODEL	
1241M	BAROMETRIC ALTITUDE TRANSDUCER

CODE	CALIBRATED ALTITUDE RANGE DESIRED
1	−1,000 to 10,000 feet
2	S.L. to 10,000 feet
3	−1,000 to 15,000 feet
4	S.L. to 15,000 feet

CODE	CALIBRATED TEMPERATURE RANGE DESIRED
A	−20° to +50°C
B	−55° to +71°C

CODE	OUTPUT VOLTAGE DESIRED
1	0.5 mVDC/ft. (0.0 VDC at lowest calibrated altitude)
2	0.0 to 10.0 VDC (0.0 VDC at lowest calibrated altitude)

1241M	1	A	2	← TYPICAL MODEL NUMBER

Rosemount Inc.

POST OFFICE BOX 35129 MINNEAPOLIS, MINNESOTA 55435

PHONE: (612) 941-5560 TWX: 910-576-3103 TELEX: 29-0183 CABLE: ROSEMOUNT

9/75

AN/ARC-164

THE NEW USAF STANDARD UHF RADIO FOR THE F16

Reprinted From
MICROWAVE SYSTEMS NEWS
April/May 1975

THE Magnavox COMPANY
COMMUNICATIONS PRODUCTS OPERATION
FORT WAYNE, INDIANA

AN/ARC-164: The New USAF Standard UHF Radio for the F16

Featuring 'slice' construction and all solid-state design, this 10-watt radio weighs just eight pounds and has 7000 frequency channels.

Robert A. Shaw
AN/ARC-164 Eng. Manager
Communications Products Operation
The Magnavox Company
Fort Wayne, IN 46804

Designated for use in the F16—the USAF's newest aircraft—the AN/ARC-164 is the Air Force's newest UHF radio. In addition to its use in new aircraft, the ARC-164 will ultimately replace all of USAF's current inventory of ARC-27's and ARC-34's as well as other tube-type radios such as the ARC-51 and ARC-109. It is a solid-state, modular 10-watt UHF radio that provides 7000 channels with 20 presets. The fixed-tuned, broadband transmitter has true infinite VSWR capability. ARC-164 combines small size (5x5x8 inches), light weight (8 lbs) and high reliability (1000-hr MTBF) with numerous operational features. Preset frequency and channel selection is pushbutton activated and can be changed in-flight. Its low power drain enables the pilot to use the radio on the ground without a power cart and without starting the aircraft engine.

Figure 1 illustrates the size relationship between the ARC-164 and its predecessors.

The ARC-164 front panel design was evolved through two years of Air Force-Industry review by human factors groups. Magnavox engineers performed detailed analyses regarding viewing angles, use of tactile controls, and the merits of various character types to optimize layout for controls and readouts.

Versatile Radio Family. Figure 2 shows the various units comprising the ARC-164 family currently being procured by the Air Force. A typical single-seat aircraft installation will use one or two Console/Panel-Mount (C/PM) radios or Remote R-T units with Control Box and Indicator. Two-seat installations vary with the aircraft: one Remote R-T with two Controls; two Remote R-T's with two Controls; one or two C/PM radios in the front seat with a Control Box in the rear cockpit; a C/PM in each cockpit, etc.

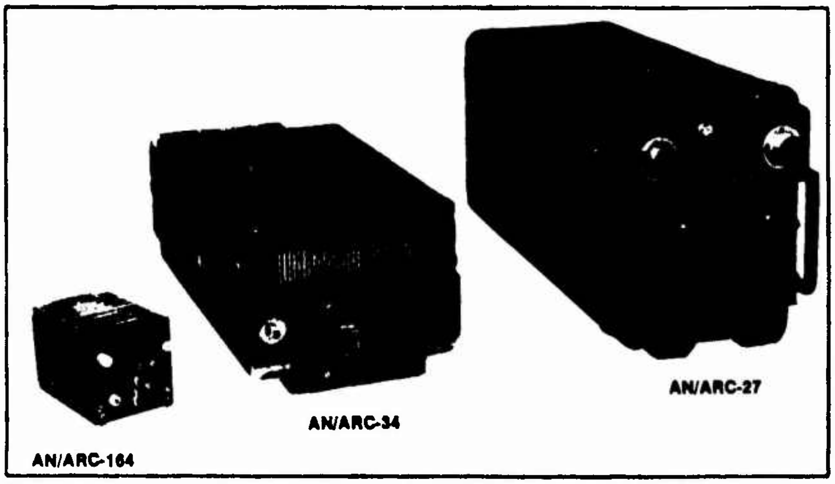


Figure 1. Three generations of airborne radios—AN/ARC-164 (left) AN/ARC-34 (ctr) and AN/ARC-27

Criteria: Performance and Total Cost-of-Ownership. In 1972, the Air Force initiated the ARC-(XXX) competition to develop the optimum UHF radio for replacement of its aging inventory. After the initial evaluation, three parallel 12-month qualification contracts were awarded to the final competitors—RCA, Collins, and Magnavox. In April 1974 Magnavox received the production contract. Choice of the AN/ARC-164 was based not only on the radio's performance, but also on several design features that provided its low initial cost, high reliability, low repair-time, and simplified logistics. All of these factors yielding a low total cost of ownership through the radio's entire life cycle.

Unique Slice Construction. ARC-164's most unique feature is the absence of the conventional chassis. The radio's various functional elements are packaged in separate, self-contained "slices", each protected by a die-cast aluminum frame and shielded for electromagnetic integrity.

Mechanically fastened together by four thru-bolts, the slices are electrically connected by a flexible harness along the bottom of the radio. On the C/PM radio and the Control Boxes, the harness extends up the back of the unit and contains all of the rear connectors. Most importantly, the functional slice

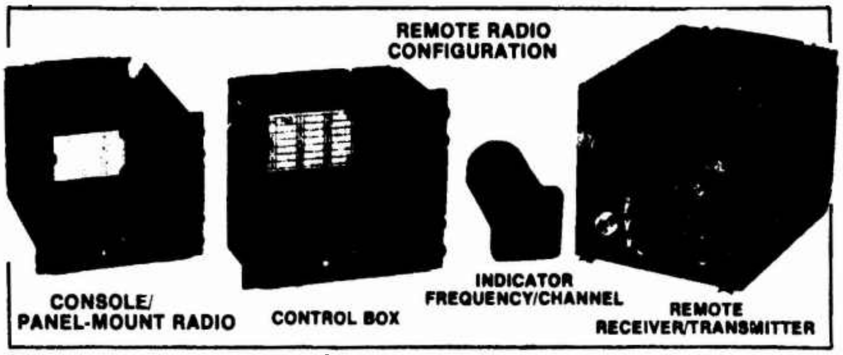


Figure 2. Major elements of the ARC-164

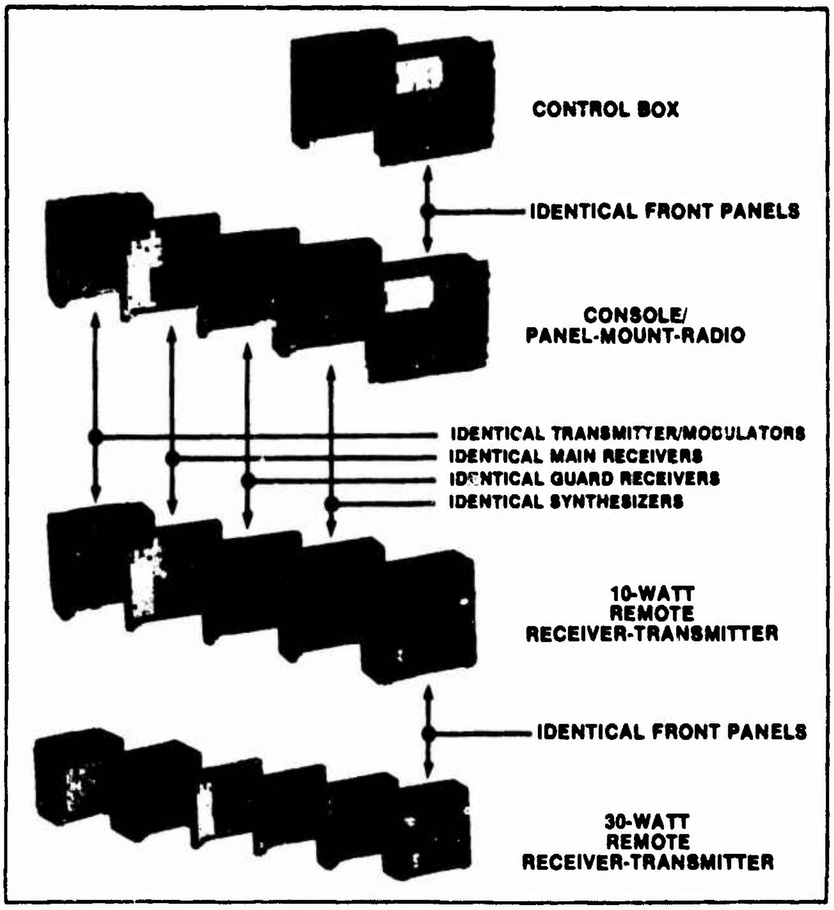


Figure 3. ARC-164 unique slice construction

Figure 4. Flex harness construction

for any one radio configuration is identical to its counterpart in any other configuration.

As shown in Figure 3, the C/PM radio consists of the front panel (containing the memory), synthesizer, guard receiver, main receiver, and transmitter (with modulator). The front panel of the C/PM radio and the front panel of the Control Box (for remote installations) are identical and interchangeable.

Those slices that comprise the Remote Receiver-Transmitter, with the exception of the front panel, are identical to the interchangeable with their counterparts and the C/PM radio. The 30-watt remote radio,* in turn, is identical to the 10-watt radio, except for the substitution of a higher-powered transmitter, an additional power supply, and the use of 5-amp instead of 2-amp fuses

Unlike the new F-16 installation, most of the ARC-164 applications will be replacements for existing ARC-27, 34, -51, -109, and others. Since all rear connectors are part of the flexible harness, using the appropriate harness easily converts the basic C/PM radio or Control Box to the desired replacement version. It is plugged into the appropriate mounting adapter which, in turn, is plugged into the aircraft with no aircraft wiring changes. This replacement operation has been timed at 5 to 15 minutes.

For Base-level maintenance, removing the bottom plate of the Radio or Control provides access to the harness which contains all of the test points required for fault isolation (see Figure 4).

In addition to its immediate advantages, the ARC-164's slice construction anticipates radio "growth" without drastic redesign. For various new applications (ECCM, secure speech, higher power, satellite communications, etc) individual slices could be changed or added without affecting the rest of the unit.

Reliability and Simplicity. To ensure high reliability, the ARC-164 uses high-reliability screened components. In the manufacturing process, all subassemblies as well as completed units undergo computerized testing at high and low temperatures.

Electrical design features of note include one-band varactor tuning of the main receiver, the single-conversion guard receiver with VHF crystal filters, the low-noise broadband transmitter, and the serial data frequency control.

Receiver Design. This radio's receiving system consists of a Main or primary receiver and a fixed-tuned Guard channel receiver. The low-level audio from the Main Receiver and the Transmitter sidetone audio are mixed and routed through the high level audio system located in the Guard Receiver.

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*Magnavox company-sponsored development. Not under Air Force Contract.

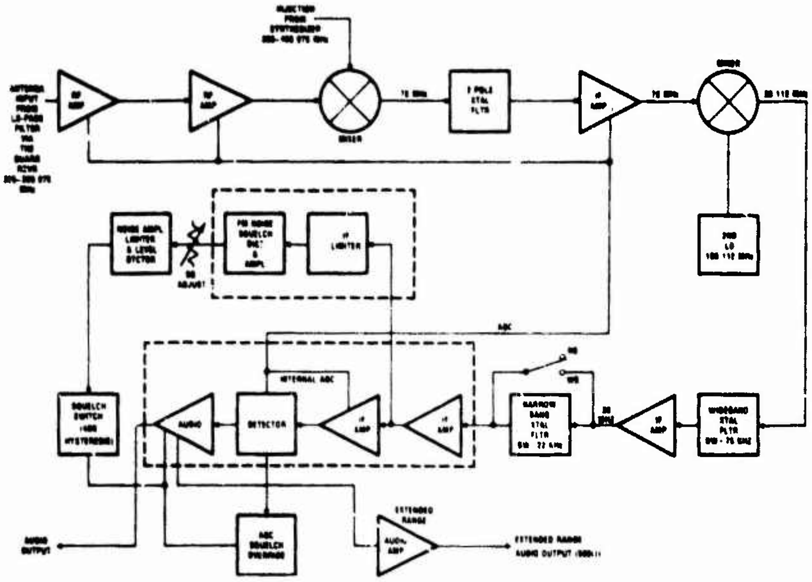


Figure 5. Main receiver block diagram of ARC-164

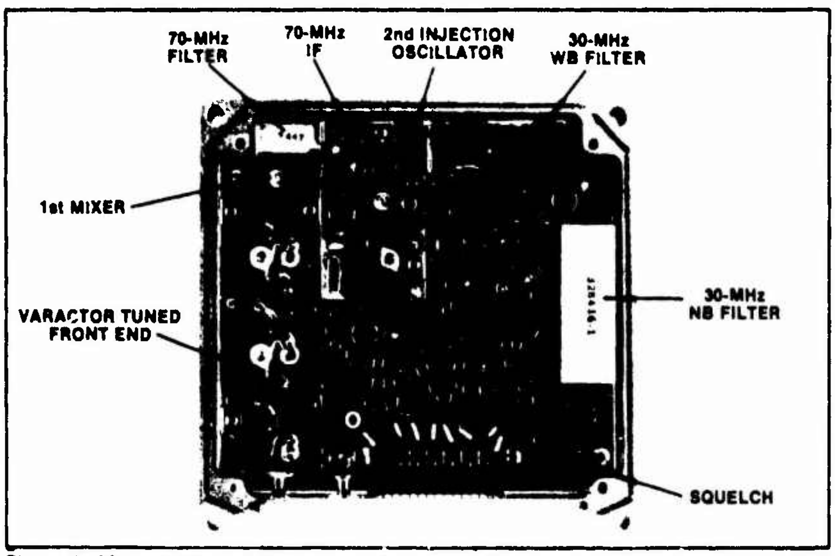


Figure 6. Main receiver

Main Receiver of the ARC-164 (Figures 5 and 6) features double-conversion superheterodyne design and is varactor-tuned over the frequency band of 225.000 to 399.975 MHz. This near-octave range is tuned in one band by use of paralleled back-to-back hyperabrupt junction varactor diodes and low series inductance techniques (Figure 7). The input VSWR over this band is maintained at less than 1.5:1; noise figure is less than 5 dB. Tuning voltage for the varactors is originated in the Synthesizer module as a linear voltage and is shaped to the desired voltage/capacitance curve by a weighting network within the receiver.

The RF stages, mixer, and second local oscillator circuits are carefully shielded to prevent stray pickup, unwanted injection, and local oscillator reradiation. Local oscillator radiation at the radio's antenna terminal is less than 5 microvolts.

Both the first and second LO signals are injected on the high side. IF frequencies have been chosen so that all harmonics of the first injection, and all but the third harmonic of the second injection, fall outside the receiver's operating range. This judicious choice of IF's greatly reduces the number of spurious reponses below those normally associated with a receiver of this complexity.

Dual-gate FET's (field-effect transistors) are used for the RF amplifiers, mixers, and first IF stage. These, plus a two-pole crystal filter following the first mixer, permit cross-modulation rejection of 80 dB (measured data: spec limit is 75 dB) to within ±1.0 MHz of the operating frequency. FET's in the RF and IF stages are AGC-controlled with 120 dB of range, which yields a 3 dB or less change in audio level with an RF input varied from 1.5 microvolts to 1 volt (measured data: spec limit is 4 μvolts to 0.5 volt).

Two IF bandwidths are available, controlled by two cascaded crystal filters. Bandwidth is selected from the radio front panel: 1) Wide-band for communication with the older ARC-27, ARC-34's, etc. and 2) narrowband for communication with more modern systems as well as for future operation with the world-wide 25-kHz Narrow Band Implementation Plan for the 1980's.

Integrated circuits are used extensively in the IF, squelch, and audio circuitry. The second injection oscillator in the Main Receiver is temperature compensated to within 1.5 parts per million over the range of −55 to +71°C. This thermal compensation, along with the 2-ppm accuracy of the Synthesizer, provides a nominal Main Receiver center frequency accuracy of ±2.5 kHz at 400 MHz.

The receiver has a remotely-controlled system for varying the bandwidth. When this mode of operation is switched in, the IF bandwidth is controlled by the wideband filter only, and the audio (25 kHz BW) is derived from the extended range output only.

For the noise-operated squelch system, a portion of the IF signal is routed to an integrated circuit that acts as an IF limiter, FM detector, and noise amplifier. Noise in the IF passband, which is detected, shaped, and amplified within the IC, is then routed through the squelch control and further

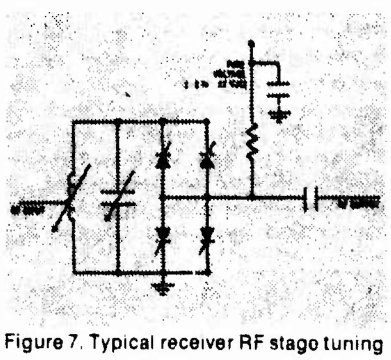


Figure 7. Typical receiver RF stage tuning

amplified. It is then baseband amplitude limited, and finally detected by hot carrier diodes. The detected voltage (at the proper level) switches states in a comparator that has about 4 dB of desirable hysteresis. This comparator output gates the audio amplifier to permit reception of signals when 1 to 15 dB RF quieting occurs, depending on the setting of the squelch adjust pot on the front panel of the radio set. By using IF noise-limiting stages in the squelch loop, overall receiver variations in gain of up to 20 dB have little effect on squelch settings.

With any noise-operated squelch system, two simultaneously received RF signals could result in a heterodyne that would appear as noise to the squelch system, causing the squelch to close. To counteract such an occurrence, a second conventional AGC squelch is activated when the RF input exceeds approximately 5 to 10 microvolts, overriding the noise-operated squelch. However, the ARC-164's use of IF baseband limiters and high-pass filtering of this noise minimizes the possibility of an inadvertent squelch activation.

In the Guard portion of the receiver is essentially the same circuitry as that in the Main Receiver, except that the RF section is fixed-tuned within a 10-MHz range, and the Guard Receiver is single-conversion. The Guard Receiver does not need selectable bandwidths. Normally encountered poor image rejection in single-conversion receivers has been eliminated by using four high-Q tuned RF circuits and a 30-MHz intermediate frequency. Image rejection in the Guard Receiver exceeds 90 dB.

Input signals from the antenna, after going through the low-pass filter that is shared by the Transmitter, are routed first to the Guard Receiver then to the Main Receiver. These signals are lightly coupled to the Guard Receiver, which has a minimum loading effect on the Main Receiver.

Also contained in the Guard Receiver is the audio power amplifier for the radio. The Guard and Main Receivers' audio signals are amplified by an integrated circuit audio amplifier to a level of 250 milliwatts (see Figure 8). The audio from both receivers is rolled off approximately 3 dB at 3.5 kHz and falls at a rate of 18 dB per octave by use of three-pole audio filter networks.

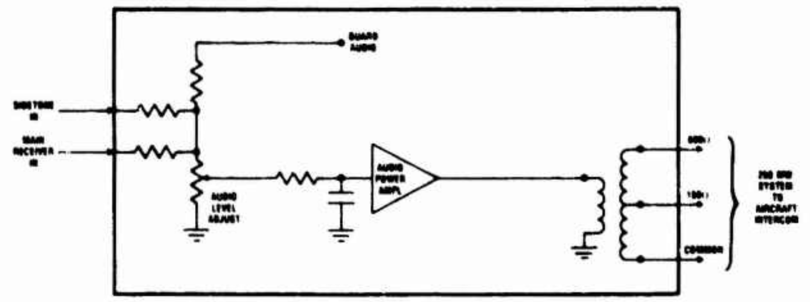


Figure 8. Receiver audio mixing

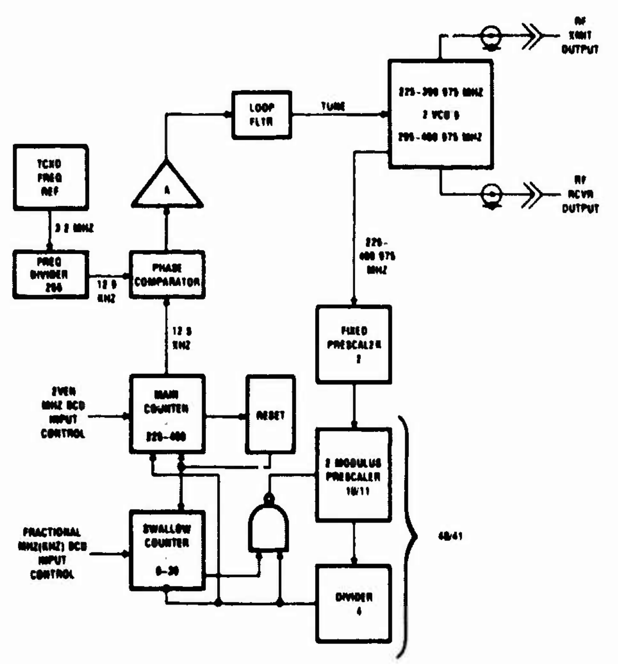


Figure 9. Synthesizer block diagram

Synthesizer Design. AN/ARC-164 incorporates an indirect frequency synthesis approach utilizing a 2-modulus prescaler (÷10/÷11) as depicted in Figure 9. This approach yields selectable RF outputs at any one of 7000 frequencies between 225.000 and 399.975 MHz (25-kHz spacing) for transmitter carrier, or any one of 7000 frequencies between 295.000 and 469.975 MHz (25-kHz spacing) for receiver high-side mixer injection. Most of the integrated circuits used are of "MSI" complexity.

Of particular interest in this design is the use of an extremely high frequency ECL MSI device, which provides a 2-modulus division capability for the programmable divider. This device, supplied by Plessey Semiconductor to military grade specifications in a DIP package, allows the use of a fixed prescaler of only 2, resulting in a reference frequency of 12.5 kHz.

Figure 9 outlines the basic phase-locked loop used. This ECL flip-flop, which can operate at speeds of 470 MHz, reduces the signal to within the operating range of the 2-modulus counter. This counter output is combined with two flip-flops, thereby providing a variable division modulus of 40 and 41. This modulus allows organization of the counters to accept directly the standard BCD frequency control without encoding. The main counter divides by a number equivalent to the number of MHz desired at the output, and the swallow counter divides by one for every additional 25-kHz increment desired at the output (max of 39). During the count cycle a "41" division is accomplished under control of the swallow counter and all other counts are at a "40" division.

As an example, if an RF output of 229.975 MHz is desired, the main counter will divide by 229 and the swallow counter by 975/25 = 39. The overall division will be:

Division = (Fixed Prescaler) × 41 (Swallow) + 40(229-Swallow)
= (2) x [41 x 39 + 40(229-39)]
= 2 (1599 + 7600)
= 18,398

$\frac{229.975}{18,398} = 12.5$

(Required for phase comparator)

The 12.5-kHz reference input for the other side of the phase comparator is provided by a 3.2 MHz TCXO with 2-ppm accuracy, followed by a fixed divider of 4 x 64 = 256. Incorporated in the phase comparator are both coarse and fine tuning to maintain stable loop performance over the full temperature range of −54°C to +71°C.

Three hyperabrupt-junction varactor-tuned VCO's are used to cover the 225- to 400-MHz range. With the receiver offset requirement of 70 MHz, VCO #1 operates in transmit mode from 225 to 299.975 MHz, VCO #2 operates for the receiver mode 295 (225 + 70) to 369.975 (299.975 + 70) and the remaining transmit frequencies of 300 to 399.975 MHz. VCO #3 covers the remaining receive mode frequency of 370 (300 + 70) to 469.975 (399.975 + 70).

Transmitter Design. This solid-state unit comprises two main subassemblies: the Modulator and the Transmitter. For packaging convenience, the ARC-164's Power Supply is also contained in the overall transmitter assembly. Generating the required regulated voltages for the radio, the Power Supply is short-circuit protected and designed to withstand MIL-STD-704 transients and over-voltage tests. It also shuts down the ARC-164 to prevent damage at any time that the input voltage exceeds 36V. Normal operation returns automatically when the input voltage drops below that level.

Figure 10 is a simplified block diagram of the overall transmitter assembly. The audio and tone circuits are conventional, utilizing operational amplifiers. A series-diode-type audio peak-limiter is employed. This type limiter is used for its excellent limiting action and the ease with which limiting levels may be varied. Following the limiter is an electronically-switched low-pass filter with two cut-off frequencies—3.5 kHz and 25 kHz. The filter output is applied to the power and modulation control circuits.

The low-level RF amplifiers are designed for low noise figure to ensure that the noise level of the RF input signal is not increased. Low noise JAN TX type transistors are used in this circuitry.

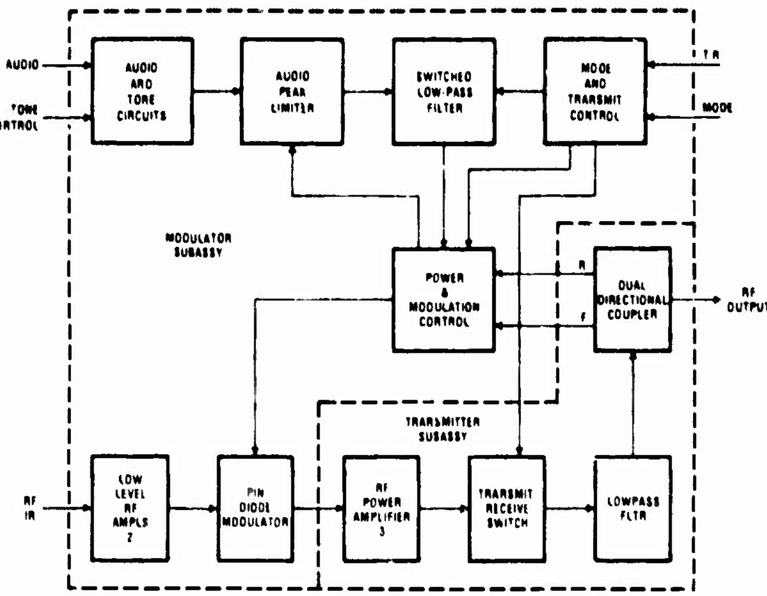


Figure 10. Simplified block diagram of ARC-164 transmitter

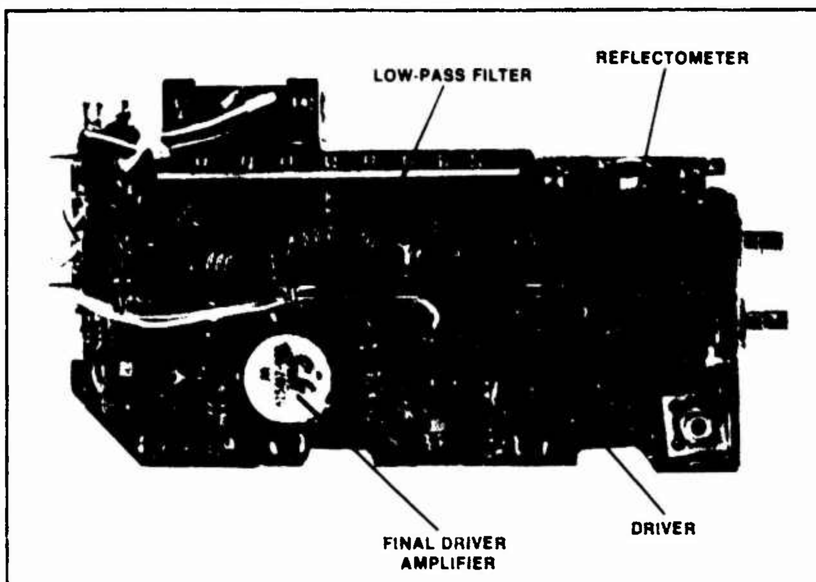


Figure 11. Transmitter subassembly

Shown in Figure 11, the Transmitter subassembly contains the RF power amplifiers, transmit-receive switch, low-pass filter, and dual directional coupler. The RF power amplifiers utilize state-of-art power devices chosen for reliability and ruggedness. The circuitry is conventional, featuring printed wiring boards and discrete components. The dual directional coupler samples and rectifies the RF power output a[illegible]ny reflected RF power at the Trans[illegible] These forward and reflected sample voltages are applied to the power and modulation control.

Along with the power and modulation control, the PIN diode modulator is the heart and brain of the transmitting system; it controls the RF gain of the overall transmitter chain. The transmitter's gain is varied to produce the amplitude modulation by varying the attenuation of the PIN diodes. Attenuation of these devices is controlled by

FWD75-940

the Power and Modulation Control, or PMC.

In PMC a DC reference voltage is compared against the average DC forward power reference from the directional coupler to adjust the PIN diodes for an average carrier output power of 10 watts. The processed AC modulating voltage is summed to the DC reference voltage, thus causing the PMC to vary the PIN diodes in such a manner that the sampled and rectified RF power from the directional coupler compares to the DC reference voltage and the summed modulating voltage. PMC loop gain has been adjusted to provide a carrier distortion of less than 10% under all environmental conditions. Nominal distortion is 2 to 3% at full 90% modulation with 10-watt output carrier. This PMC system also provides for a minimum of +80% positive modulation over the full frequency range of 225 to 400 MHz.

The PMC also linearly reduces the transmitter power output and the audio peak limiter limiting level for conditions of low supply voltage. A thermostat is used to reduce these levels when the transmitter heat sink temperature reaches 100°C. Sidetone audio from the detected RF enevelope is routed through the Guard Receiver audio amplifier.

Memory Design. ARC-164 utilizes an electronic memory (developed by the Quadri Corporation) to store the 20 preset channel frequencies. Any of the 20 channels can be preset either on the ground or in flight by selecting the desired channel number and frequency, and depressing the "preset" pushbutton. The memory itself utilizes ferrite cores to provide non-volatile storage of data (frequency data preset into the memory is retained indefinitely even though the system may have no power applied).

The core stack is operted in an NDRO (Non-Destructive Read Out) mode, thereby reducing power dissipation. This mode also minimizes time required for the "read" operation, since the cores do not have to be restored to the original state after readout as in conventional DRO (Destructive Read Out) memories. NDRO also eliminates the DRO's requirement for power line sensors and "data save" circuitry.

The NDRO technique utilizes the reversible flux properties of the ferrite cores. A read current less than that required to completely switch the core is passed through the core, thus inducing a small signal into the sense winding through the same core due to the flux change in the core. Through the use of multiple cores and windings per bit, the sense line output from the core stack is increased to a level of approximately 200 mV, which is sufficient to utilize inexpensive and power saving discrete sense amplifiers.

Also contained in the memory slice is the circuitry needed to generate a 4-wire serial data system, which is used to tune the Remote Radio Set and operate a remote Frequency/Channel Indicator. This serial data system is designed so that two or more systems may be linked together, but enabled one at a time and so provide multiple control locations for a single remote R/T unit. The parallel frequency control outputs from the memory also provide this capability, permitting multiple control locations for a single C/PM R/T unit.

Summary. In the ARC-164 the Air Force has procured a radio set that is cost conscious in its design and utilizes state-of-the-art concepts coupled with responsibly mature technology that is obtainable from multiple sources in industry. It meets the key criteria of 1) long MTBF, 2) ability to undergo the rigorous environments encountered in today's fighter aircraft and 3) ease of maintenance. ■

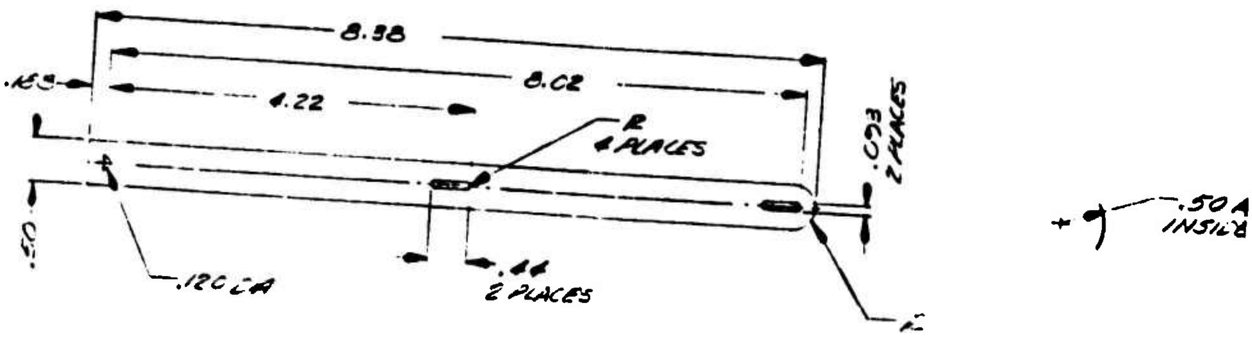
Acknowledgements

While many people have been involved in the development and design of the ARC-164, the one individual most responsible for its "birth" and growth has been E.D. Aldred, Director of Engineering for Magnavox' Communications Products Operation. Mr. Aldred conceived the original Model CA-713, forerunner of the ARC-164, with its innovative slice construction, high reliability, and small size.

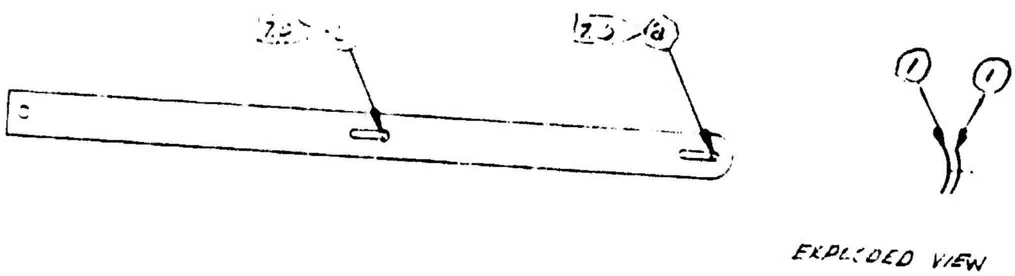
Particular recognition is also owed to—

Thomas L. Hall for digital design
John R. Lentz for the synthesizer design
Richard W. Stroud for receiver design
Robert W. Yankowiak for transmitter design

as well as to Taulbee Mountz and Robert H. Thorngate, USAF Project Engineers, for overall technical direction and guidance.



PART -1



ASSY -801

Magnavox Drawing #955933

SENSE, ANTENNA
ASSEMBLY

VORTEX AIRSPEED SENSORS

J-TEC ASSOCIATES, INC., 317 7TH AVENUE S.E., CEDAR RAPIDS, IOWA 52401
319/366-7511

THE VORTEX AIRSPEED SENSOR

When air flows past an obstruction a turbulence is created. Above a certain minimum velocity this turbulence assumes a regular pattern of vortices as illustrated on the cover. The spacing between these vortices is a well-defined constant and is approximately two-and-one-half times the diameter of the obstruction. Furthermore, the vortex formation frequency (F) can be formulated as follows:

$$F = \frac{Sv}{d}$$

where F : Hz
v : fluid velocity (ft/sec)
d : diameter of strut (ft)
S : Strouhal number (0.207)

In the J-Tec airspeed sensors, this vortex frequency is detected by passing a confined cw ultrasonic beam through the vortex path* formed behind the strut or obstruction in the air flow. Each pair of vortices causes one cycle of amplitude modulation to be impressed on the carrier signal due to the beam scattering effect of the oppositely rotating vortices. The vortex frequency is therefore a function of velocity, and airspeed can be measured without moving parts and without the calibration of secondary transducers.

*Patented technique

VA-210/220 SPECIFICATIONS

Range	2 to 200 knots (optional models up to Mach 0.85)	**Power**	18 to 32 VDC, 100 ma
Accuracy	± 1% Full Scale	**Output (typical)**	70 Hz/knot (frequency) 50 mv/knot (analog)
Response to speed changes (frequency)	⅛ inch air movement	**Size (inches)**	3.0L × 2.0W × 4.5H (VA-210) 4.0L × 0.9W × 2.6H (VA-220) 3.5 × 3.5 × 5.5 (Processor)
Immune to		**Weight (lbs)**	0.75 (VA-210) 0.375 (VA-220) 1.5 (Processor)
Pitch	Up to 30		
Yaw	Up to 15		

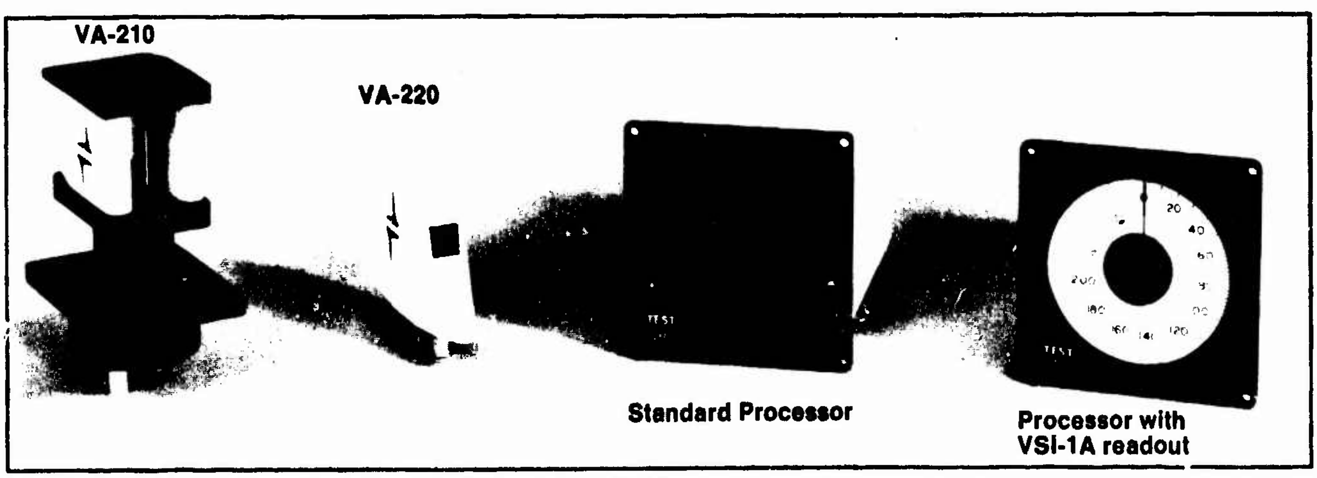
INSTALLATIONS AT

- Edwards AFB
- Wright Patterson AFB
- NASA Langley
- Arnold Air Dev. Ctr.
- Bell Helicopter
- NAEC Philadelphia
- Ft. Rucker
- U.S. Navy Pax River
- NASA Ames
- NASA Edwards
- Sikorsky
- NOAA
- MB-B

ON AIRCRAFT

- TH-1F
- CH-3E
- OH-58A
- SH-3
- Cessna 310
- BO-105
- UH-1
- YOH-6
- H-53
- S-58T
- H-500
- DC-6

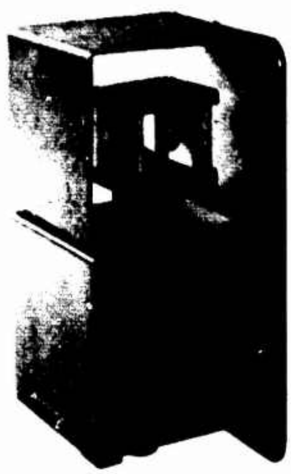
SENSORS and PROCESSORS (not pictured: VSI-1D digital display)



THE VORTEX AIRDRAFT SENSOR

FOR USE IN MINING AND INDUSTRY

VA-213



VA-214

Just as the VA-210 can be modified for use at speeds of up to Mach 0.85, it also can be altered to operate at very low speeds, as low as 50 FPM. This is accomplished simply by increasing the diameter of the strut or obstruction in the flow.

As altered, the true airspeed sensor becomes an airdraft sensor for use in mine and ventilation shafts, air conditioning or heating plenums, air intakes, diffusers and other applications for accurate airspeed measurement at low velocities. The sensor is immune to changes in humidity and temperature, and operates over a range of minus 20 to plus 200 degrees Fahrenheit.

The VA-213 is a portable, battery-powered instrument, while the VA-214 is designed for fixed operation at strategic monitoring points in shafts or ducts. The extended range feature is available in both the VA-213 and VA-214 Models.

VA-213/214 SPECIFICATIONS

Range		75 to 3000 FPM or 150 to 10,000 FPM (Extended range)
Accuracy		±2% Full Scale
Repeatability		Better than 1% of Point
Response (frequency)		Equivalent to time required for ½ inch air travel at any velocity
Output (typical)	Frequency	0.25 Hz/FPM or 0.7 Hz/FPM (Extended range)
	Analog	0 to 2.5V FS (VA-213) 0 to 5V FS (VA-214)

Power	Internal, 9V Battery or External, +8 to +12 VDC @ 20 ma (VA-213) External, 12 VDC @ 20 ma (VA-214)
Construction	Sensor aluminum. Plastic case for VA-213, steel for VA-214
Size (inches)	2⅞ L × 2⅛ W × 2H (active sensor) 3 × 8½ × 7 (case, VA-213) 9H × 5W × 4¼ D (case, VA-214)
Weight	3 lbs. (VA-213) 4 lbs. (VA-214)

Intrinsically Safe — Total circuit capacity less than 100 micro-farads. Bureau of Mines Approval pending.

MARK-10X

RADAR ALTIMETER
&
ACCESSORIES
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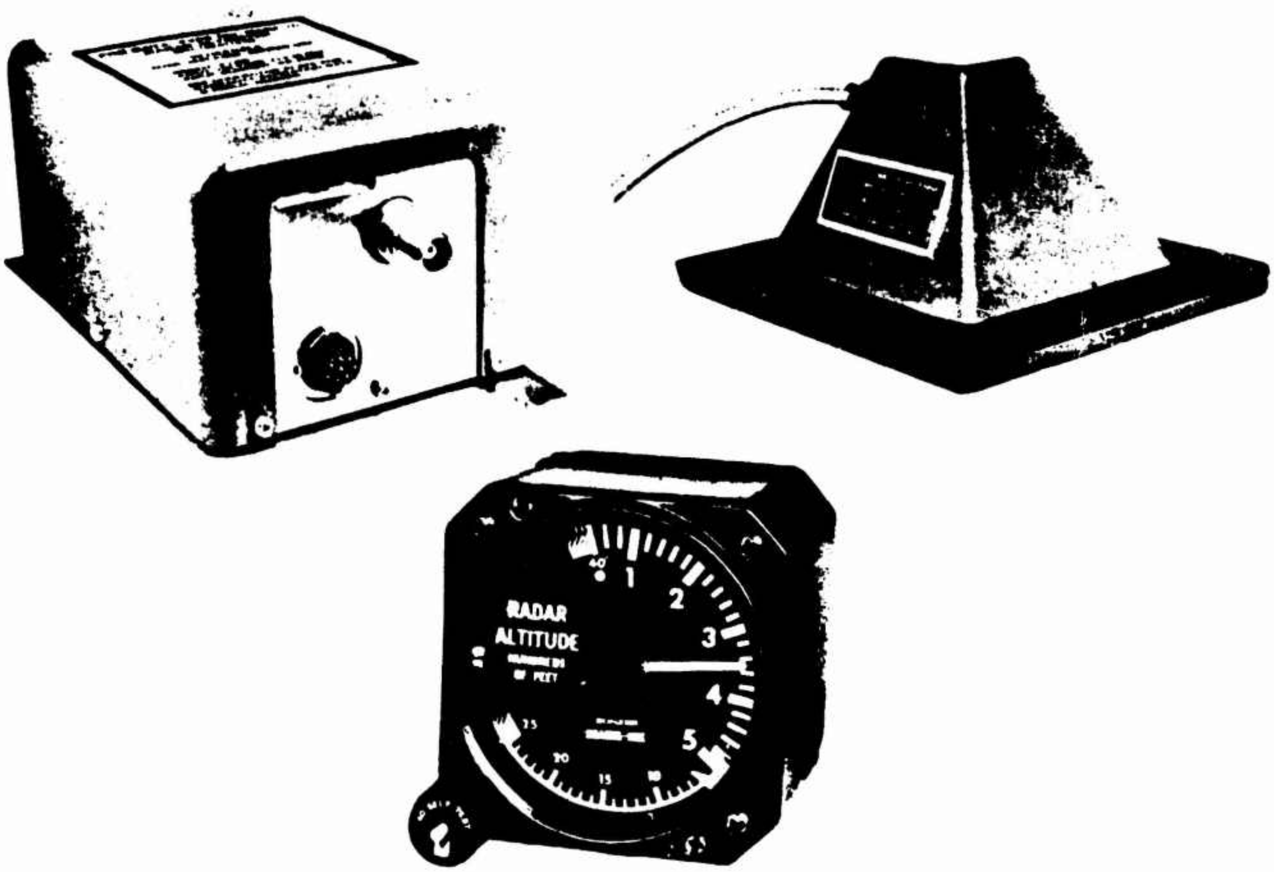


INSTALLATION INSTRUCTIONS

BONZER INC.

90th & CODY, OVERLAND PARK, KANSAS 66214 USA
913 + 888-8760

Specifications

MINI-MARK TR-ANTENNA UNIT (BPN 104-0152-00)

Transmitter	Pulse type
Pulse Width	30 nanoseconds
Antenna	1 horn type, flush style
Antenna Pattern (3 db points)	± 30° pitch ± 30° roll
Altitude Range	80 ft. to 1000 ft.
Accuracy	Better than ± 7%
Frequency	4300 MHz
Input Voltage	14 or 28 v DC
Input Current	.6 amps
Power Output	3 watts peak
Size	3.5 in. H, 5 in. W, 6 in. L (88.9 mm H, 127.0 mm W, 152.4 mm L)
Weight	2.0 pounds (0.9 kg)
Exterior Frontal Section	1.8 sq. in. (45.7 sq. mm)
Pendant Power Cable	10 inches (254.0 mm)
Antenna Hole Cutout	4.59 in. x 3.59 in. (116.58 mm x 91.18 mm)
Price	$900.00

MINI-MARK INDICATOR (BPN 104-0158-00)

Type	2 in. round, sealed, taut band, rear or front mount
Scale	Linear 80 ft. to 1000 ft.
Meter Movement	80 ft. 0.8 v 1000 ft. 10.0 v
Size	2 in. diameter x 3.5 in. deep (50.8 mm diameter x 88.9 mm deep) Standard 2 in. panel hole, 2.25 in. diameter (57.15 mm)
Weight	.5 lbs. (0.22 kg)
Price	$95.00

MINI-MARK DH SYSTEM (BPN 104-0153-00)

Input Voltage	14 or 28 v DC
Input Current	.3 amps maximum
Aural Alert	High Output Sonalert® 2 second 2800 Hz pulsing tone burst
Visual Alert	Amber DH light and flashing digit. Light intensity varies automatically
DH Reference	Incandescent digit .25 inch high. 100 thru 900 feet
Size	Display — ¾ inch (19.05 mm) diameter, 1¼ inch (31.75 mm) behind panel, 3 ft. (.9 m) prewired ribbon cable Aural Alert — 1¾ in. (44.45 mm) diameter, 1½ in. (38.1 mm) behind panel. Mounts in 1⅛ in. (28.575 mm) hole Converter — 4 in. (101.6 mm) W, 5 in. (127.0 mm) L, 1 in. (25.4 mm)
Weight	Total DH system 0.60 lbs. (0.27 kg)
Price	$390.00

Warranty

Bonzer, Inc. has manufactured the MINI-MARK Radar Altimeter of quality materials and components. This equipment [illegible] tested and inspected before it leaves [illegible] provides the following warranty [illegible]

LIMITED WARRANTY CERTIFICATE

[illegible] 90th and Cody, Overland Park, Kansas 66214, U.S.A. [illegible] to the original purchaser [illegible] each new [illegible] MARK consisting of a TR-antenna unit and [illegible] shall be free from defects in material and [illegible] under normal use [illegible] which it is [illegible] does not cover any part which [illegible] Bonzer, Inc. Service Department [illegible] in any way so as to adversely [illegible] or has been subject to misuse [illegible]

THIS WARRANTY IS IN LIEU OF [illegible] GUARANTIES OR EXPRESS WARRANTIES.

THIS WARRANTY AND ANY EXISTING IMPLIED WARRANTY SHALL BE FOR 15 MONTHS FROM THE ORIGINAL DATE OF SHIPMENT FROM THE FACTORY. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation of any implied warranty may not apply to you.

As the sole and exclusive remedy [illegible] express or implied, including any [illegible] warranty, the unit or component covered by this warranty having a defect in material or workmanship will be repaired or [illegible] Bonzer, Inc. [illegible] replaced [illegible] returned to Bonzer [illegible] within the warranty period [illegible]

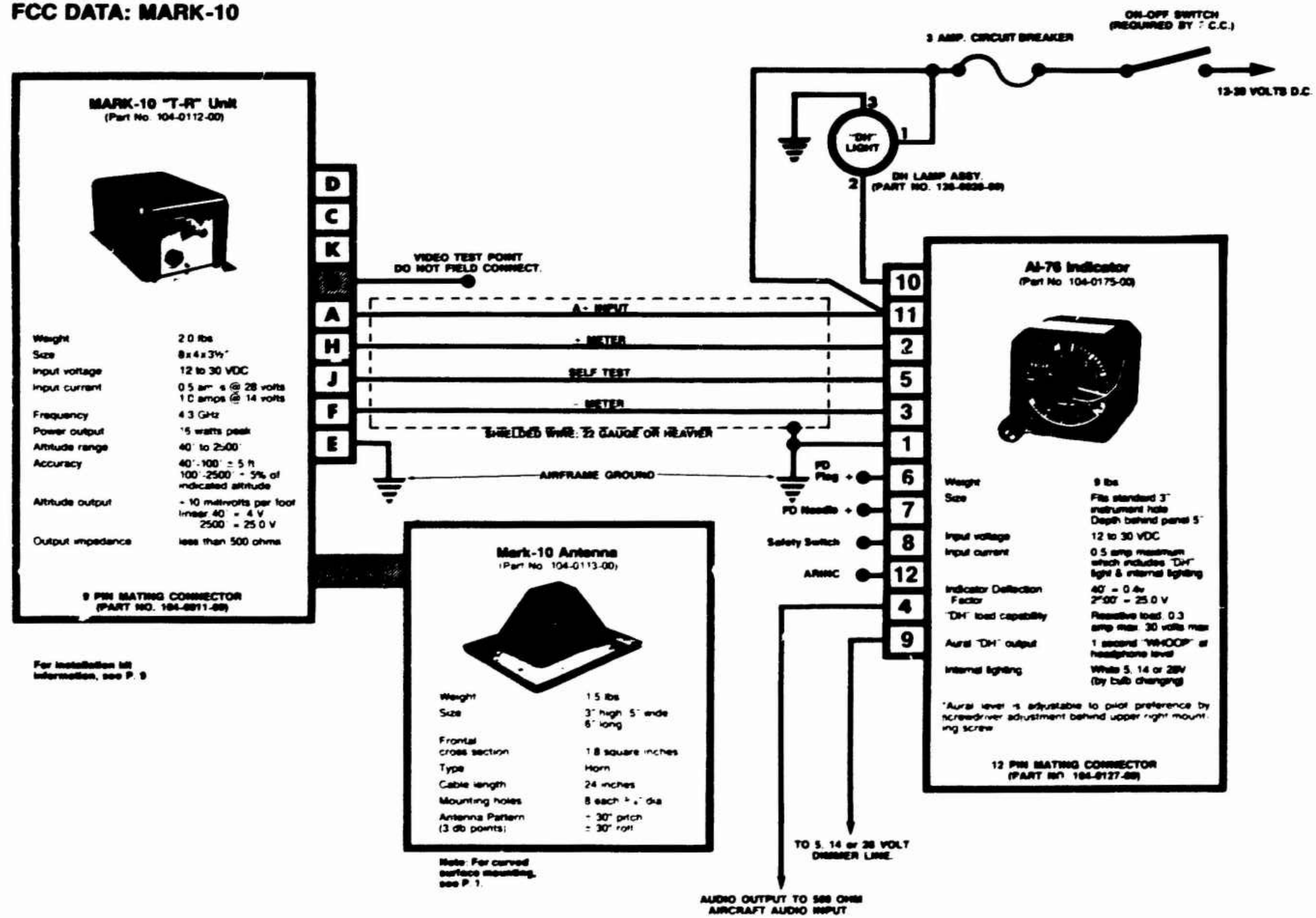
If repair or replacement is an ineffective remedy, as the sole and exclusive remedy, Bonzer, Inc. will return to the original purchaser for use that amount of the purchase price received by Bonzer, Inc. To be entitled to this warranty remedy the original purchaser for use must:

1. Discontinue use of the equipment as soon as a defect or malfunction is recognized.
2. Remove [illegible] from the aircraft [illegible] Properly [illegible] the unit to: Service Department [illegible] 90th and Cody, Overland Park, Kansas 66214, U.S.A.

The first original purchaser for use bears the [illegible] removal and reinstallation, and expense and risk of [illegible] paid to the factory of the service [illegible] and the return shipment, and any other expenses incurred by him incident to this warranty.

Under no circumstances shall Bonzer, Inc. be liable to the original purchaser for use or any other person or entity for incidental or consequential damages as defined by the Uniform Commercial Code for breach of [illegible] Some states do not allow the exclusion or limitation of incidental or consequential damages [illegible] may not apply to you. [illegible]

FCC DATA: MARK-10



BONZER INC.
90th and Cody / Overland Park, Kansas 66214 / Phone Area Code 913 888-8760

DEALER PRICE LIST
AVIONICS PRODUCTS
EFFECTIVE JANUARY 1, 1978

MARK-10X RADAR ALTIMETER SYSTEM

PART NUMBER	DESCRIPTION	LIST	DEALER (LIST-35%)
104-0176-00	MARK-10X System, Round Indicator complete Includes TR Unit, AI-76 Round Indicator, Antenna, and Installation Kit	2295.00	1491.75
104-0119-00	MARK-10 System, Vertical Indicator complete Includes TR Unit, Vertical Indicator, Antenna, A70-5 Adjustable DH Switch & Installation Kit	2295.00	1491.75
104-0121-00	MARK-10 System, Horizontal Indicator complete Includes TR Unit, Horizontal Indicator, Antenna, A70-5 Adjustable DH Switch, & Installation Kit	2295.00	1491.75
104-0112-00	T-R Unit	1495.00	971.75
104-0175-00	AI-76 Round Indicator	590.00	383.50
104-0117-00	Vertical Indicator	255.00	165.75
104-0118-00	Horizontal Indicator	255.00	165.75
104-0113-00	Antenna	210.00	136.50
104-0116-00	A70-5 Adjustable DH Switch (includes DH Light)	295.00	191.75
104-0038-00	A72-1 Aural DH Alert	40.00	26.00
104-0129-00	Curved Surface Antenna Gasket	20.70	13.46
104-0128-00	Installation Kit - Round Includes 1-12 Pin Connector, 1-9 Pin Connector, TR Mounting Plate, Backup Plate with screws and nuts, and DH Light	48.40	31.46
104-0114-00	Installation Kit - Vertical or Horizontal Includes 2-9 Pin Connector, TR Mounting Plate, Backup Plate with screws and nuts and DH Light (special decal).	48.40	31.46

ALL PRICES AND SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

BPN 149-0128-00

Specifications

MINI-MARK TR-ANTENNA UNIT (BPN 104-0152-00)

Transmitter	Pulse type
Pulse Width	30 nanoseconds
Antenna	1 horn-type [illegible]ush style
Antenna Pattern (3 db points)	± 30° pitch ± 30 roll
Altitude Range	80 ft to 1000 ft
Accuracy	Better than ± 7%
Frequency	4300 MHz
Input Voltage	14 or 28 v DC
Input Current	6 amps
Power Output	3 watts peak
Size	3.5 in H, 5 in W, 6 in L (88.9 mm H, 127.0 mm W, 152.4 mm L)
Weight	2.0 pounds (0.9 kg)
[illegible]terior Frontal Section	1.8 sq in (45.7 sq mm)
[illegible]ndant Power Cable	10 inches (254.0 mm)
[illegible]tenna Hole Cutout	4.59 in x 3.59 in (116.58 mm x 91.18 mm)
Price	$900.00

MINI-MARK INDICATOR (BPN 104-0158-00)

Type	2 in round, sealed taut band, rear or front mount
Scale	Linear 80 ft to 1000 ft
Meter Movement	80 ft 0.8 v 1000 ft 10.0 v
Size	2 in diameter x 3.5 in deep (50.8 mm diameter x 88.9 mm deep) Standard 2 in panel hole, 2.25 in diameter (57.15 mm)
Weight	0.5 lbs (0.22 kg)
Price	$95.00

MINI-MARK DH SYSTEM (BPN 104-0153-00)

Input Voltage	14 or 28 v DC
Input Current	3 amps maximum
Aural Alert	High Output Sonalert® 2 second 2800 Hz pulsing tone burst
Visual Alert	Amber DH light and flashing digit. Light intensity varies automatically
DH Reference	Incandescent digit .25 inch high. 100 thru 900 feet
Size	Display [illegible] inch (19.05 mm) diameter 1¼ inch (31.75 mm) behind panel 3 ft (.9 m) prewired ribbon cable Aural Alert [illegible] 1¾ in (44.45 mm) diameter, 1½ in (38.1 mm) behind panel. Mounts in 1⅛ in (28.575 mm) hole Converter [illegible] 4 in (10[illegible] mm) W. 5 in (127.0 mm) L. 1 in (25.4 mm)
Weight	Total DH system 0.60 lbs (0.27 kg)
Price	$390.00

Warranty

Bonzer, Inc. has manufactured the MINI-MARK Radar Altimeter of quality materials and components. The equipment is thoroughly tested and inspected before it leaves the factory. Bonzer, Inc. provides the following warranty.

LIMITED WARRANTY CERTIFICATE

Bonzer, Inc., 90th and Cody, Overland Park, Kansas 66214 U.S.A. warrants only to the original purchaser [illegible] that each new MINI-MARK consisting of a TR-antenna [illegible] indicator [illegible] supplied by it shall be free from defects in material and workmanship under normal use for which it is manufactured. This warranty does not cover any part which in the judgment of Bonzer, Inc.'s Service Department, has been repaired or altered in any way so as to adversely affect its performance or reliability or has been subject to misuse, negligence or accident.

THIS WARRANTY IS IN LIEU OF ALL OTHER GUARANTEES OR EXPRESS WARRANTIES.

THIS WARRANTY AND ANY EXISTING IMPLIED WARRANTY SHALL [illegible] FOR 15 MONTHS FROM THE ORIGINAL DATE OF SHIPMENT FROM THE FACTORY. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation on any implied warranty may not apply to you.

As the sole and exclusive remedy for breach of any warranty express or implied, including any subsequently made written warranty, the unit or component covered by this warranty having a defect in material or workmanship will be repaired or, at Bonzer, Inc.'s option, replaced if the [illegible] equipment [illegible] returned to Bonzer, Inc. or an authorized [illegible] service agency within the warranty period with transportation charges prepaid. If repair or replacement is an ineffective remedy, as the sole and exclusive remedy, Bonzer, Inc. will return to the original purchaser for [illegible] that amount of the purchase price received by Bonzer, Inc. To be entitled to this warranty remedy the original purchaser for use must:

1. Discontinue use of the equipment as soon as a defect or malfunction [illegible]ized.
2. Remov[illegible] from the aircraft.
3. Properly [illegible] the unit to Service Department, [illegible] factory, 90th and Cody, Overland Park, Kansas 66214, U.S.A.

The first original purchaser for use bears the expense of removal and reinstallation, the expense and risk of loss of shipment of the part to the factory or the service agent and the return shipment and any other expenses incurred by him incidental to the warranty.

Under no circumstances shall Bonzer, Inc. be liable to the original purchaser for use or any other person or entity for any incidental or consequential damages as defined by the Uniform Commercial Code for breach of any warranty. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

[illegible] warranty gives you specific legal rights and you may also [illegible] which vary from state to state.

BONZER INC.

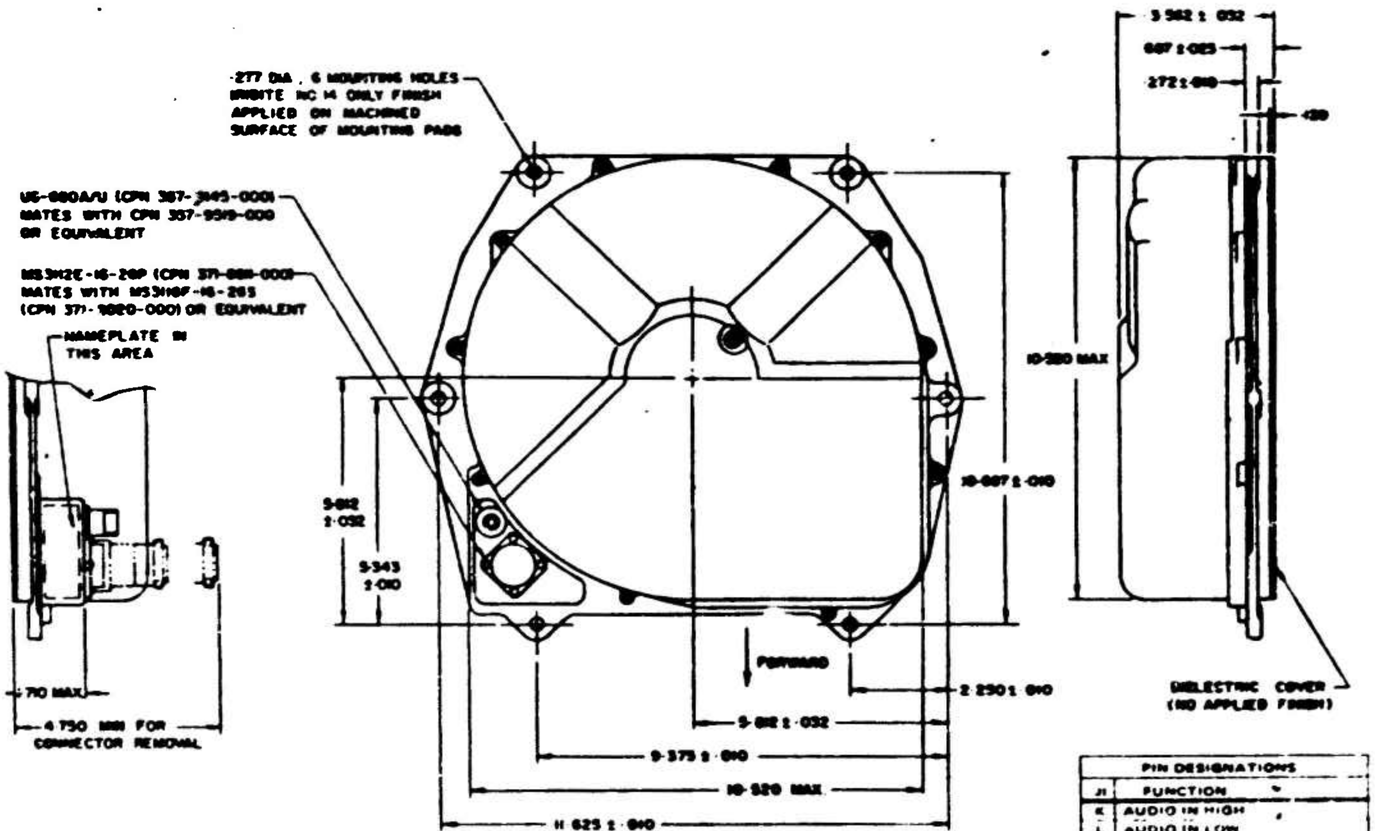
90th and Cody / Overland Park, Kansas 66214 / Phone Area Code 913 888-6760

DEALER PRICE LIST
AVIONICS PRODUCTS
EFFECTIVE SEPTEMBER 1, 1976

MINI-MARK RADAR ALTIMETER

PART NUMBER	DESCRIPTION	LIST	DEALER (LIST--30%)
104-0163-00	Mini-Mark System Includes TR-Antenna Unit, Indicator and Installation Kits	995.00	696.50
104-0152-00	Mini-Mark TR-Antenna Unit and Installation Kit	900.00	630.00
104-0158-00	Mini-Mark Indicator and Installation Kit	95.00	66.50
104-0159-00	Mini-Mark TR-Antenna Installation Kit	22.10	15.47
104-0160-00	Mini-Mark Indicator Installation Kit	22.70	15.89
104-0153-00	Mini-Mark DH System Includes Display, Aural Alert, Converter, and Installation Kit	390.00	273.00
104-0162-00	Mini-Mark DH System Installation Kit	8.80	6.16
104-0165-00	A70-6 DH System Includes A70-6 Adjustable Decision Height Switch, DH Light Assembly, A72-1 Aural DH Alert and Installation Kit	335.00	234.50
104-0161-00	A70-6 DH System Installation Kit	29.80	20.86
104-0129-00	Curved Surface Antenna Gasket	20.70	14.49

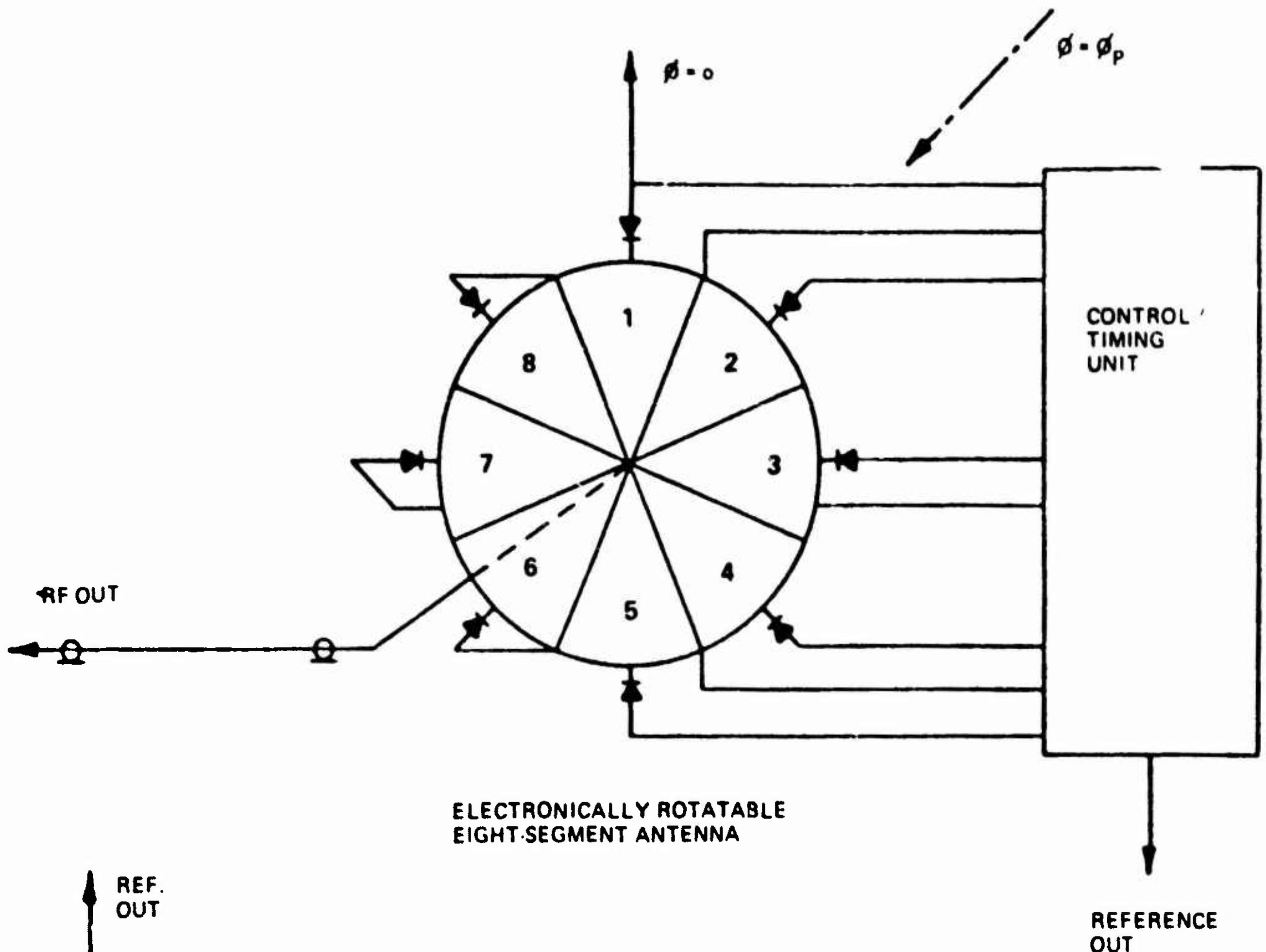
BPN 149-0085-00



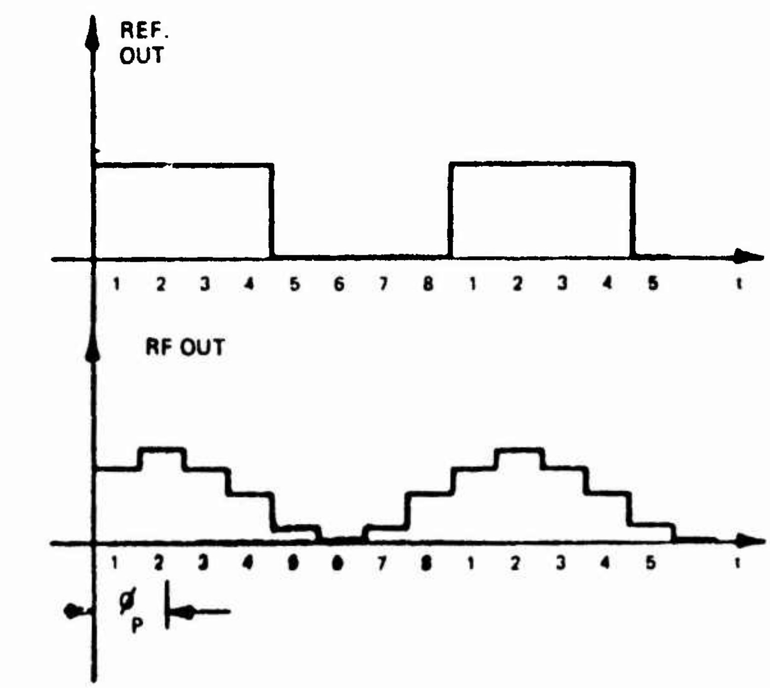
PIN DESIGNATIONS	
J1	FUNCTION
K	AUDIO IN HIGH
L	AUDIO IN LOW
M	27 VDC IN
A	27 VAC 400 HZ IN
X	DC GROUND
P	AC GROUND/BEARING OUT Z
B	BEARING OUT X
C	BEARING OUT Y
D	ON/OFF GROUND
E	CONVERTER ON
H	RESERVED (OTI)
N	RESERVED (OTI)
W	RESERVED (OTI)
G	RESERVED (TEST)
F	RESERVED (TEST)

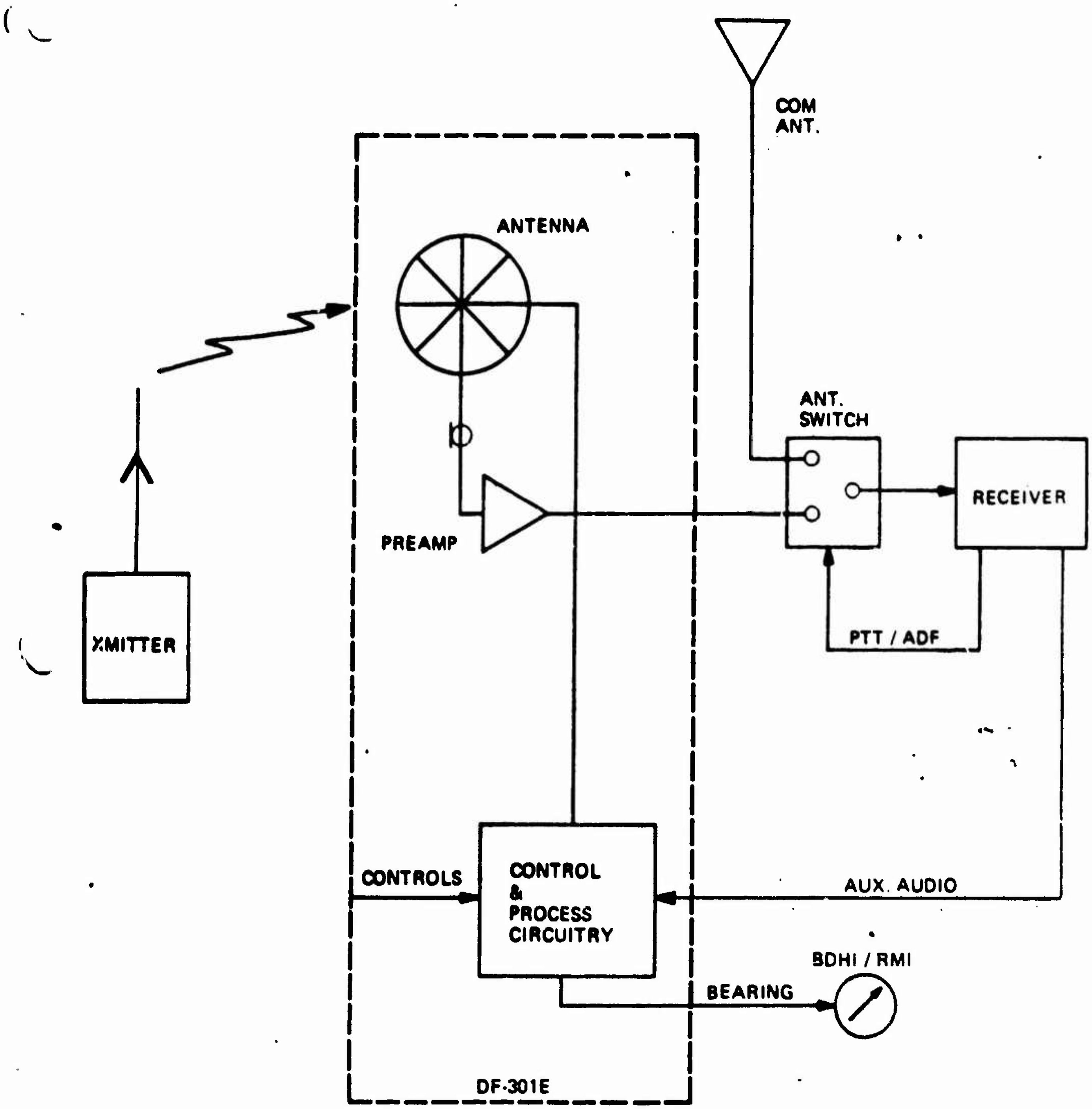
DF-301E OUTLINE AND INSTALLATION

ANTENNA ROTATION



ELECTRONICALLY ROTATABLE EIGHT-SEGMENT ANTENNA





SYSTEM BLOCK DIAGRAM

SPECIFICATIONS

ELECTRICAL

Power Input	26 VAC, 400 Hz, 1 Ø, 6 VA (Maximum) 27.5 VDC, 17 Watts (Maximum)
Frequency Range	100 - 400 MHz
Preamplifier	Gain 17 DB Minimum 100-400 MHz Noise Figure – 6 DB Maximum Blocking – Up to 50 MV, RF Input
Bearing Accuracy	2.5° RMS (Standard Conditions)
Indication Lag	Less than 4° at an aircraft turning rate of 3° per second.
Damping	Overshoot less than 10° (No adjustment required)
System Sensitivity	50 microvolts per meter in a vertically polarized field.

ENVIRONMENTAL

Altitude	70,000 ft.
Temperature	Mil-E-5400 Class 2. -54°C to + 71°C continuous at sea level. + 10°C at 70,000 ft continuous, + 95° at sea level intermittant.
Humidity	Waterproof
Vibration	Mil E 5400 N Curve IV .1 inches DA. 5-20 Hz 2 G 20-32 Hz .036 DA 32-70 Hz 10 G 70-500 Hz
Shock	15G, 11 millisecond duration 30G, 11 millisecond duration, crash safety

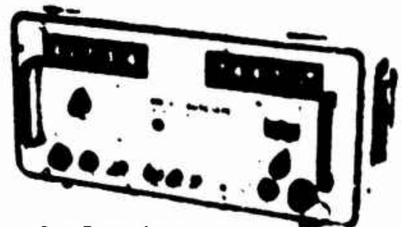
MECHANICAL CHARACTERISTICS

Size	3.6 inches (8.82 cm) Height 11.63 inches (28.1 cm) Width 7 pound (3.178 Kg) Weight
Mounting	Same Hole Pattern as AS909/ARA-48 Antenna Adapter available for AS-578/ARA-25 Antenna

What the system includes

AUTOTAPE MODEL DM 40 automatic positioning system for the measurement of two slope distances to a moving vehicle. The equipment includes

Quantity	Description
1	Interrogator and RF Assembly with 15' and 100' antenna cable set
2	Responder and RF Assembly with 15' and 100' cable set
1	Omnidirectional Antenna
2	60° Horn Antenna
	Each Interrogator and Responder is provided complete for battery operation (less battery) with headset, instruction manual, 15' power cable and transport case. Also included are two tripods, three psychrometers, and three altimeters



Two-Range Interrogator

Horn antenna and responder

Optional Equipment Available

AUTOTAPE PRINTER—this unit provides a printed record of each Autotape range measurement

AUTOTAPE DATA RECORDER—this system records on magnetic tape Autotape ranges, manually entered data, and data from other equipments in a form suited for direct computer processing

AUTOTAPE PLOTTER AND PROCESSOR—this system will convert the two Autotape ranges and plot them in scaled rectangular coordinates

Cubic experience is at your service

Cubic's leadership in the field of electronic distance measurement is your assurance. Cubic's work in the development of survey satellites and the Electrotape distance measuring equipment tells in the reliable performance of Autotape. And though Autotape's operation is simplicity itself, Cubic will not set you adrift with only an instruction manual. Experienced Cubic engineers will spend one week with your crews in familiarization routines.

Cubic's warranty and service means a minimum of costly downtime

Cubic provides a 1-year unconditional warranty. If you need service, Cubic offers rapid free service (including air-freight transportation within the United States). There are no extended and costly delays while crews wait for needed equipment. 35320530

Ordering information and financing

To order, contact Cubic Corporation and indicate whether you are interested in direct purchase or financing.

AUTOTAPE MODEL DM 40

SPECIFICATIONS

Operating Range 100 kilometers between antenna ½ power points over radio line of sight

Probable Range Accuracy 50 cm + 1 100,000 × range

Maximum Range Rate 200 knots—higher rate possible with reduced resolution

Operating Frequency 2900 to 3100 mcs

Transmitted Power 1.0 watt maximum

Frequency Stability 1 part per million

Antenna Beam Width (½ Power)

Responder (Horn)	60° Horizontal	10° Vertical
Interrogator (Omni)	360° Horizontal	10° Vertical

Display 5-digit numerical to 9999.9 meters for both ranges based on index of refraction of 320 N

Display Rate
- Automatic 1 per second
- Fine 2 per second
- Intermediate/Coarse 1 per ⅓ second
- External On manual or electronic command, 1 per second maximum

Data Outputs 20 line binary coded decimal 1-2-4-8 for each range, 0 and +6 volts into 1K

Communications Integral two-way communications from Interrogator to all Responders

Range Resolution
- Automatic and fine 10 centimeters
- Intermediate Coarse 1 meter

Physical Characteristics
- RF Assembly 3¼"H 6½"W 7½"D 6 lbs
- Interrogator 11"H 20½"W 21"D 55 lbs
- Responder 8"H 14"W, 11"D, 22 lbs
- Horn 38"×24"×5½", 20 lbs
- Omni 15" long 1¼" diameter, 1 lb

Temperature
- Operating −10° to +50°C
- Storage −40° to +60°C

Power Requirements
- Interrogator 100 watts, 12 vdc
- Responder 75 watts, 12 vdc
- Either unit available for 24 vdc operation

Electronic Surveying Division

CUBIC CORPORATION

9233 Balboa Avenue, San Diego, California 92123
Phone (714) 277-6780 · Cable Address "CUBIC"

653

Giving You The Leading Edge

To 70,000 Feet - With Honeywell's

HIGH ALTITUDE RADAR ALTIMETRY

A record of excellent performance by Honeywell systems, during literally millions of flight hours and in all types of aircraft, provides the expertise we have applied to ensure that the HG7196 High Altitude Radar Altimeter System (HARA) offers you the ultimate in reliability, accuracy and maintainability.

Designed to accurately measure and display absolute altitudes throughout the range from zero to 70,000 feet, this pulse radar system includes a receiver-transmitter, an analog/digital height indicator, and two high-gain, planar-array antennas.

While the technology and construction utilized is highly similar to that incorporated in Honeywell's general purpose and missile radar altimeters, recently-developed components and circuitry have been incorporated to ensure optimum system performance at all altitudes.

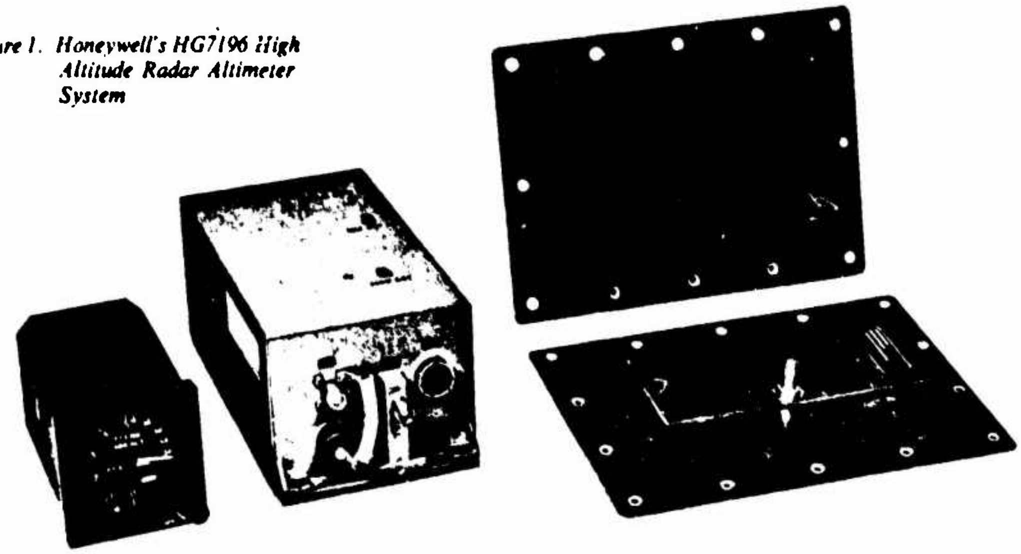
Why Pulse Radar?

State-of-the-art in radar altimetry, Honeywell systems incorporate pulse radar to prevent range errors during pitch and roll, guarantee all-weather accuracy in heavy rain or snow. Accuracy is also maintained over ice and snow, and there is complete immunity to doppler effect.

Why Leading Edge?

Honeywell's proven concept of radar altimetry includes leading edge tracking for highly-accurate, actual-range indication to the nearest object. Averaging errors are eliminated.

Figure 1. Honeywell's HG7196 High Altitude Radar Altimeter System



Giving You The Leading E

To 70,000 Feet -

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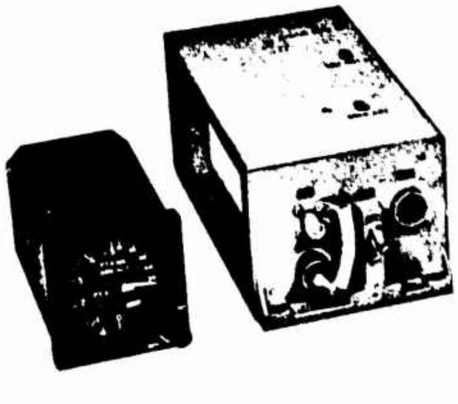
Figure 1. Honeywell's HG7196 High Altitude Radar Altimeter System



CHARACTERISTICS OF THE HG7196 HARA

RECEIVER-TRANSMITTER

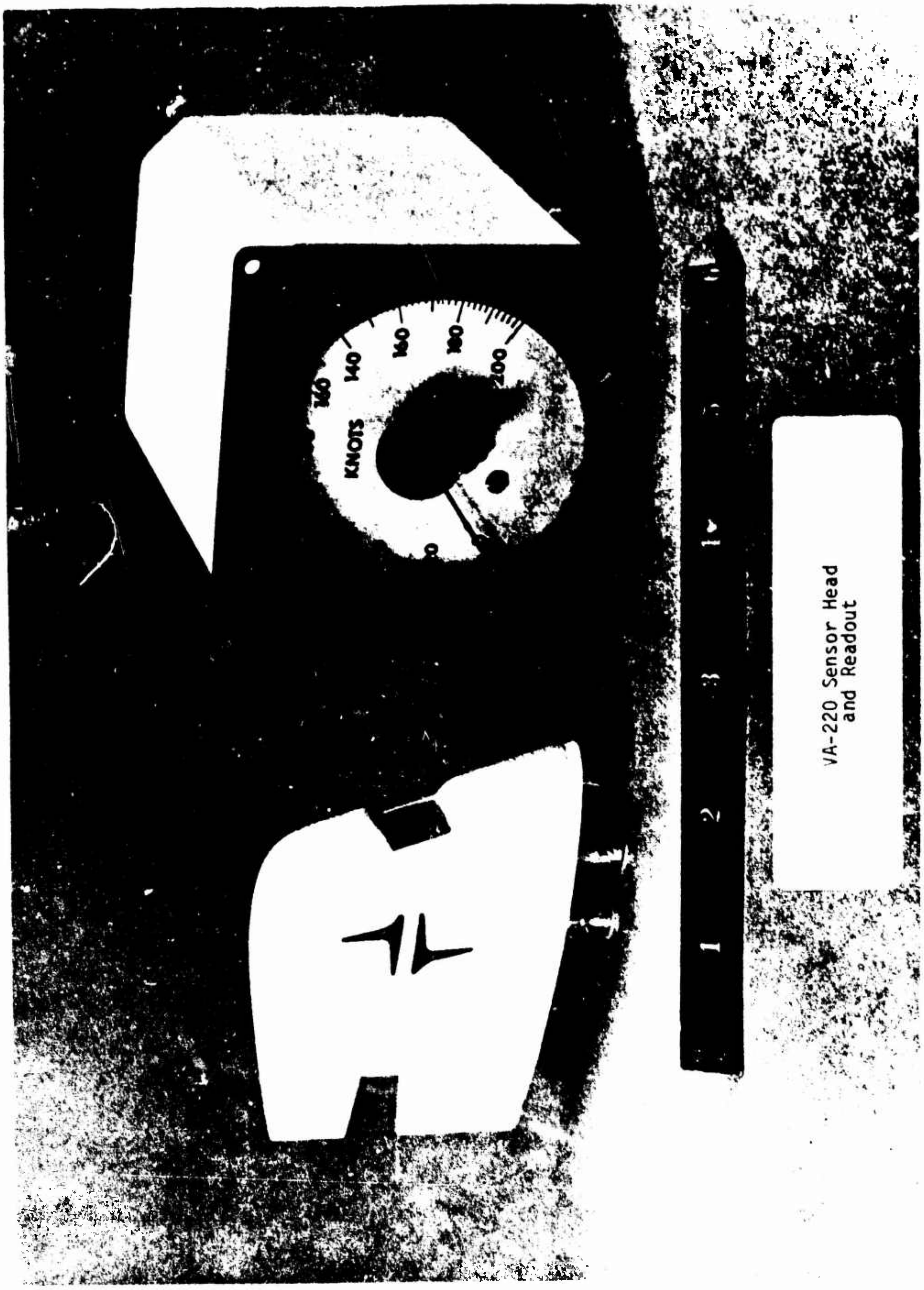
- Type — RF pulse-modulated absolute altitude radar altimeter
- Operating Frequency — 4.3 GHz
- Size — 168 cu in
- Weight — 6.5 lbs
- Altitude Range — 0 to 70,000 feet
- Temperature Range —
  - Operating: −55°C to +71°C
  - Non-operating: −65°C to +95°C
- Output Signals
  - Digital
    - Full scale: 70,000 feet
    - Resolution: 1 foot
    - Word: 24 bits serial
  - Analog
    - Full scale: 5,000 feet
    - Scale factor: 2.0 mv ft
- Accuracy —
  - Digital: ±(5 ft + 0.5%)
  - Analog: ±(10 ft + 2%)
- Input Power — 35 watts at 28 vdc
- Predicted Reliability — 5,250 hours MTBF
- Altitude Track Rate — 2,000 ft s
- Pulse Repetition Frequency — 5 kHz ± 10%
- Service Life — 10,000 hours
- Operational Stability — 1,000 hours
- Warm-Up Time — 60 seconds max.
- Transmit Power — 500 watts (wide pulse)
- Loop Sensitivity — 146 dB minimum
- Receiver Sensitivity — 90 dB
- Maneuverability (Pitch and Roll) —
  - ±10 deg at 70,000 feet
  - ±20 deg at 35,000 feet
- Self-Test — pre-flight and in-flight

HEIGHT INDICATOR

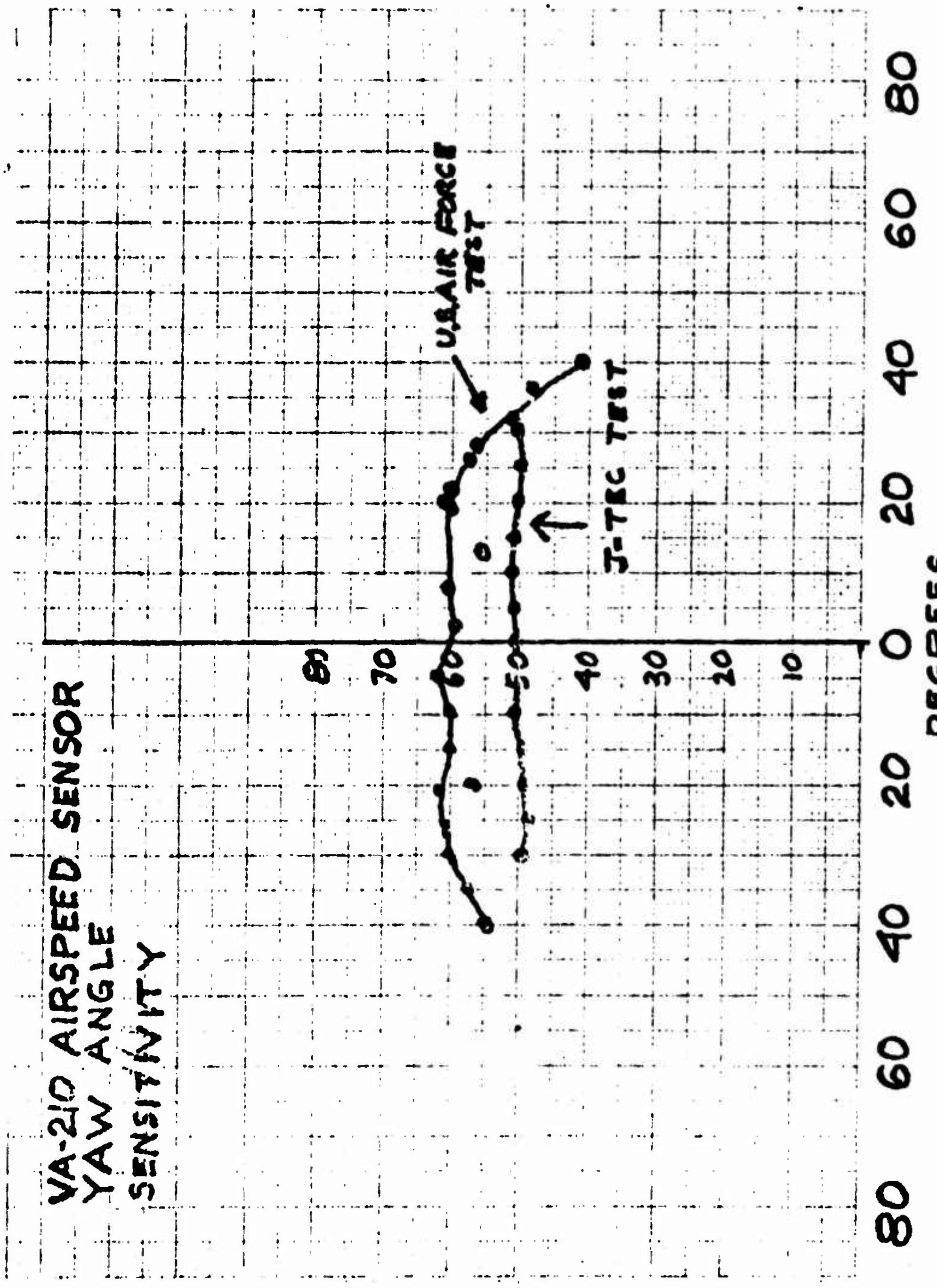
- Analog and Digital Indication of Altitude
- Size — 56 cu in.
- Weight — 2.5 lbs
- Power — 15 watts, 28 vdc
- Variable Low-Altitude Warning Light
- Predicted Reliability — 9,345 hours
- Comprehensive Built-In Test Circuitry

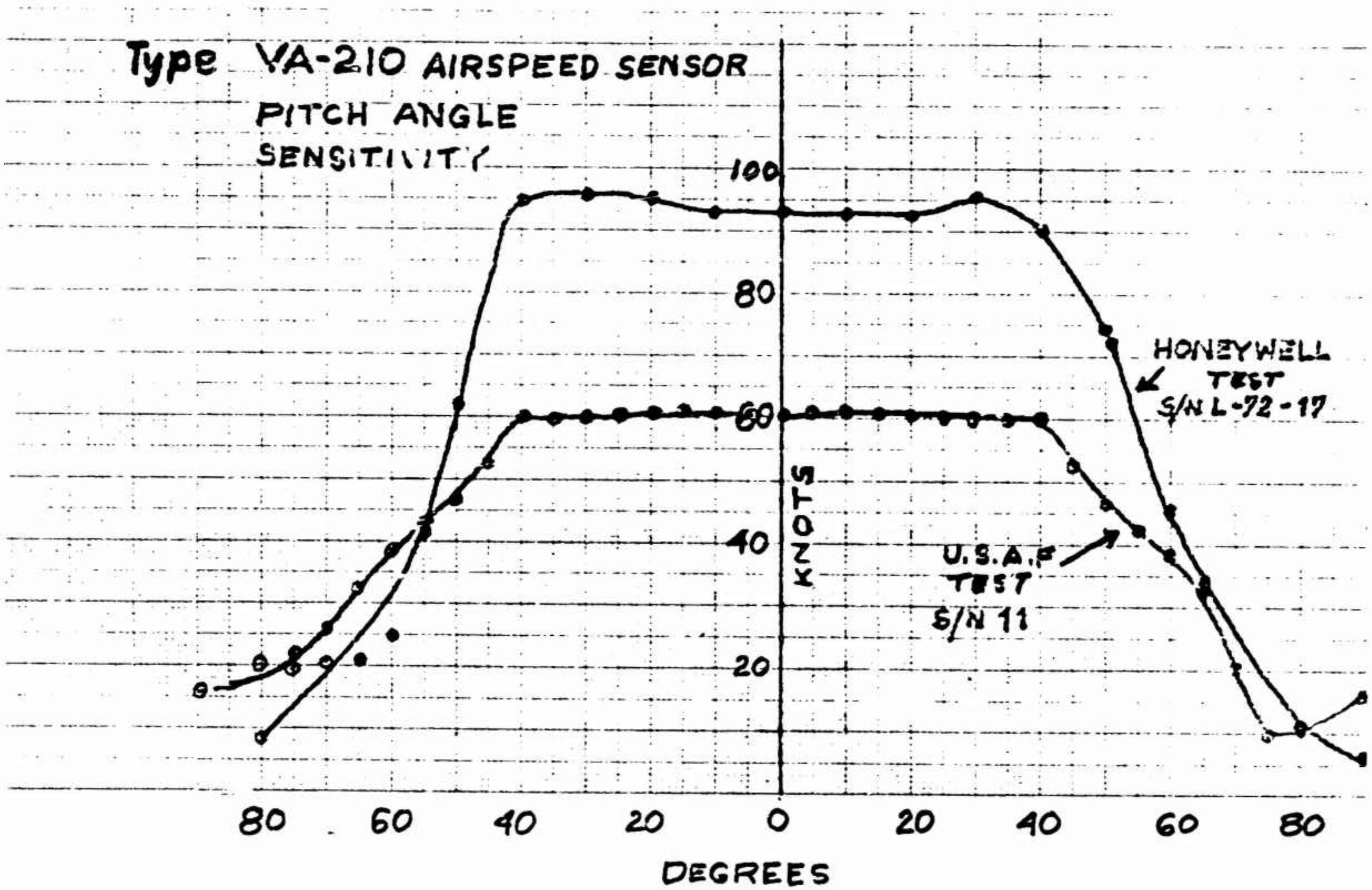
ANTENNAS

- Planar Array Microstrip Construction
- Second Harmonic Filter
- 20 deg Full-Beam Width, E and H Planes (3 dB points)
- Minimum Gain — 16 dB
- Size — 7 x 10 x 0.25 inches
- Weight — 1.0 lbs
- Impedance — 50 ohms
- VSWR — 1.8 max. between 4250 and 4350 MHz
- TNC Connector



VA-220 Sensor Head
and Readout


VA-210 AIRSPEED SENSOR
YAW ANGLE
SENSITIVITY
U.S. AIR FORCE TEST
J-TEC TEST
DEGREES
80
70
60
50
40
30
20
10
0
20
40
60
80


Type VA-210 AIRSPEED SENSOR
PITCH ANGLE
SENSITIVITY
HONEYWELL
TEST
S/N L-72-17
U.S.A.F
TEST
S/N 11
KNOTS
100
80
60
40
20
80
60
40
20
0
20
40
60
80
DEGREES

SYSTEM SPECIFICATIONS

Mini-Ranger Data Processor

Operating speed	1.0 μsec basic cycle time
Memory capacity	Up to 64 kilobytes 12 or 16 kilobytes standard programmable read-only memory
Computational accuracy	40 bits binary precision plus 8 bits exponent and sign
Position fixing interval	0.5 sec
Operator interface	Serial ASCII, 10 or 30 characters per second. RS-232C and/or 20 mA current loop compatible.
Input/Output	9 I/O connectors available TTL compatible, parallel BCD interface, standard
Time-of-day clock	Internal, 24-hour crystal controlled. Settable through operator's console.
Operating voltage	115/230 VAC, 50-400 Hz 24 VDC optional
Power input	100 watts, maximum
Physical dimensions	44 x 46 x 14 cm
Weight	16 KG
Operating temperature range	0 to +50°C

Track Indicator

Display	Horizontal meter type. Both steering and distance traveled displayed. Alarm light to indicate invalid data.
Scale	Steering: Selectable; 5, 20, or 80 units/division. Normal and reverse indicators. Chainage: Calibrated in percent of course complete.
Operating voltage	Powered from Data Processor
Physical dimensions	11.5 x 23 x 18 cm
Weight	1.8 KG

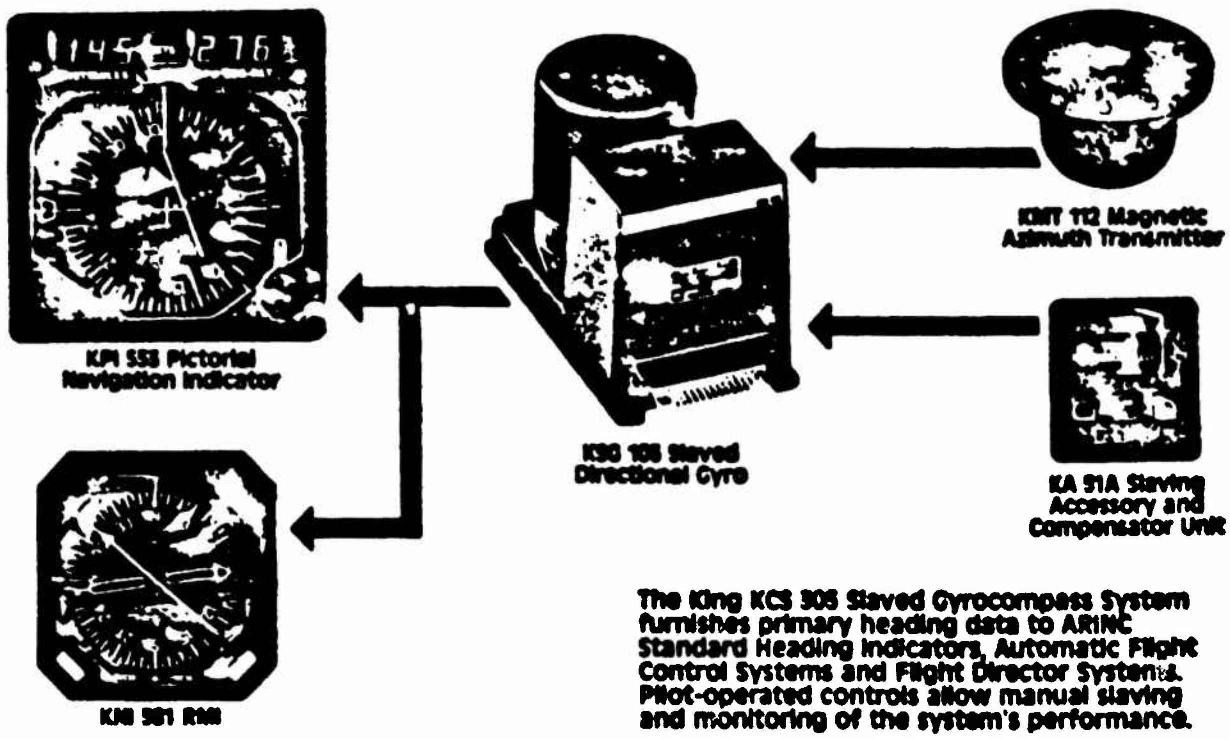
BASIC SYSTEM SPECIFICATIONS

Range	37 km (20 nm) line of sight; 20 to 200 km (10 to 108 nm) options available
Accuracy	3 meter (10 ft) probable range error
Frequency	5400 to 5600 MHz.
Coding	Four selectable codes using pulse spacing (16 codes optional).
Range Console	
Range readout	Displays channels A and B simultaneously with range units available in meters (standard); yards or feet optional.
Output to peripherals	Binary coded decimal, TTL, (8421) parallel
Operating voltages	115/230 volts AC, 50-400 Hz (optional 24-30 volts DC power).
Power consumption	77 watts (AC); 57 watts (DC)
Operating temperatures	0 to +50°C.
Dimensions	43 x 45.7 x 14 cm (17 x 18 x 5.5 in.) table mount.
Weights	14.5 kg (32 lb) AC power; 12.7 kg (28 lb) DC power.
Receiver Transmitter Unit	
Antenna	6 dB omnidirectional (25° elevation).
Operating temperatures	-40 to +60°C.
Power	Supplied by range console.
Dimensions	15.8 x 23.5 x 16.5 cm (6.25 x 9.25 x 6.25 in.).
Weight	2.3 kg (5 lb) with brackets.
Reference Stations	
Antenna	13 dB sector (75° azimuth, 15° elevation).
Operating voltages	24-30 volts DC.
Power consumption	13 watts (nominal).
Operating temperatures	-54 to +71°C.
Dimensions	14 x 26 x 16.5 cm (5.5 x 10.25 x 6.5 in).
Weight	2.3 kg (5 lb) less antenna.

Mini-Ranger III Positioning System

Frequency range	5400 to 5600 MHz
Range	20 NM standard 40 NM and 100 NM optional
Coding	Four selectable codes standard, 16 codes optional
Probable range error	± 3 meters
Range readout	Six digits, meters standard, yards or feet optional. Dual simultaneous readout (single, alternate readout in Nav MODE)
Digital output	BCD, TTL compatible +8421 logic
Operating voltage	
Range console	115/230 VAC, 50-400 Hz standard 24-30 VDC optional
Reference stations	24-30 VDC
Operating temperature ranges	
Range console	0 to +50°C
Receiver-transmitter	-40 to +60°C
Reference stations	-54 to +71°C
Physical dimensions	
Range console	44 x 46 x 14 cm
Receiver-transmitter	16.6 x 23 x 14 cm*
Reference stations	16.6 x 26 x 14 cm*
Weight	
Range console	14.5 KG
Receiver-transmitter	2.3 KG
Reference stations	2.3 KG
Power requirements	
Range console	100 watts, maximum
Receiver-transmitter	Powered from range console
Reference stations	13 watts, nominal

*(*Including mounting brackets but not antenna)*



The King KCS 305 Slaved Gyrocompass System furnishes primary heading data to ARINC Standard Heading Indicators, Automatic Flight Control Systems and Flight Director Systems. Pilot-operated controls allow manual slaving and monitoring of the system's performance.

The King KCS 305 Gold Crown Gyrocompass System.

The KMT 112 Magnetic Azimuth Transmitter mounts in the wingtip or tail and senses the direction of the earth's magnetic field. It transmits this information to the KSG 105 Slaved Directional Gyro, where the information is processed to provide gyro-stabilized heading information to the Autopilot, Flight Director and compass cards on the PNI and RMI.

The KSG 105 Slaved Directional Gyro has Dual ARINC type synchro transmitters which are mechanically positioned for alignment by a stepper motor which responds to error signals developed in the flux valve control transformer. Tracks the true or slaved magnetic heading in ¼ degree increments.

Slaving rates are determined by the mode of operation. In the "free" mode, slaving can be manually set to the fast rate of 10° per second.

In the "slaved" mode, automatic fast slaving at 10° per second occurs during gyro spin up following turn-on. Thereafter, automatic slaving will continue at the slow, normal rate of 3° per minute.

The "compass" flag will appear on your PNI while the system is in fast slave rate and will disappear when normal slave rate is attained. Whenever the KA 51A is cycled to "free" mode and then back to "slave" mode, automatic fast slaving will occur for up to 20 seconds.

The KA 51A Slaving Accessory is a small panel mounted unit that displays the slaving error between the KMT 112 Azimuth Transmitter and KSG 105 Directional Gyro on an illuminated meter. Three pushbuttons are provided below the meter. The center pushbutton provides "Slaved Gyro" mode when the button is "in" and "Free Gyro" mode when the button is "out." The other two pushbuttons provide clockwise and counterclockwise manual slaving regardless of the setting of the "Slave/Free" switch.

The KA 51A also contains circuitry for compensation of the KMT 112 Azimuth Transmitter so accurate heading is displayed in all quadrants.

The KCS 305 Slaved Gyrocompass System is a "Standard ARINC Heading Source," meaning simply that it will operate with any standard ARINC PNI, RMI, Autopilot or Flight Director system.

KING KCS 305 SLAVED GYROCOMPASS SYSTEM SPECIFICATIONS

KCS 305 System

TSO Compliance:	TSO C6c RTCA Environmental Categories KA 51A DAMAAAXXXXXX KSG 105 AAJAAAXXXXXX KMT 112 BASAAAXXXXXX
System Accuracy:	Accurate to within 2° of local magnetic heading
Power Requirements:	115 vac 400 Hz sinewave 20 VA
Warm-Up Time:	Gyro spin motor up to speed in 3 minutes at 25° C
Slaving Rate:	Normal—3 degrees per minute Fast —10 degrees per second
Slaving Sensitivity:	±0.1° when in a field strength of Hz = 0.54 gauss, Hx = .18 gauss
Altitude:	-1,000 to +45,000 feet
Humidity:	Up to 95 percent
Yaw Rate:	Up to 30 degrees per second

KSG 105 Slaved Directional Gyro

Size:	5.370 x 7.790 x 4.290 inches, nominal (13.64 x 19.79 x 10.90 cm)
Weight:	4.8 pounds (2.18 Kg)
Mounting:	Rigid mount with four #8 screws
Ambient Temperature Range:	Operating -55°C to +55°C Non-Operating -65°C to +71°C
Vibration:	.02" excursion from 5 to 55 Hz 3g from 55 Hz to 2,000 Hz

KMT 112 Magnetic Azimuth Transmitter

Size:	3.37 dia. x 1.81 high, nominal (8.55 dia. x 4.60 high, centimeters)
Weight:	0.3 pounds (136 grams)
Mounting:	Rigid mount with three #6 non-magnetic screws in a remote magnetically stable area
Ambient Temperature Range:	Operating -55°C to +55°C Non-Operating -65°C to +71°C
Vibration:	The unit will function normally with the following vibration input: Constant total excursion of .036 inches from 5 to 2,000 hertz with a maximum acceleration of 10 G

KA 51A Slaving Accessory and Compensator Unit

Size:	2.000 x 2.115 x 2.250 inches, nominal (5.080 x 5.372 x 5.715 centimeters)
Weight:	0.3 pounds (136 grams)
Mounting:	Flange mounted through the front of the instrument panel
Signal Inputs:	Slaving meter drive signal from the KSG 105
Signal Outputs:	Magnetic Azimuth Transmitter compensation outputs for N-S and E-W correction to the KSG 105. Correction range is ±30° maximum
Pilot Operated Switches:	Clockwise and counterclockwise manual slave signals to the KSG 105 Slaved, free gyro mode logic signal to the KSG 105
Ambient Temperature Range:	Operating -30°C to +55°C Non-Operating -65°C to +71°C
Vibration:	The unit will function normally with the following vibration input: a constant total excursion of .010 inches from 5-55 hertz with a maximum acceleration of 1.5 G or a constant total excursion of .010 inches from 5 to 2,000 hertz with a maximum acceleration of 0.25 G

WARNING: Avionics installations require special skills, tools and test equipment. The famous King full year warranty system is valid only for equipment installed by an authorized King Sales and Service Center.

Tomorrow's Avionics Today...from KING of course

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